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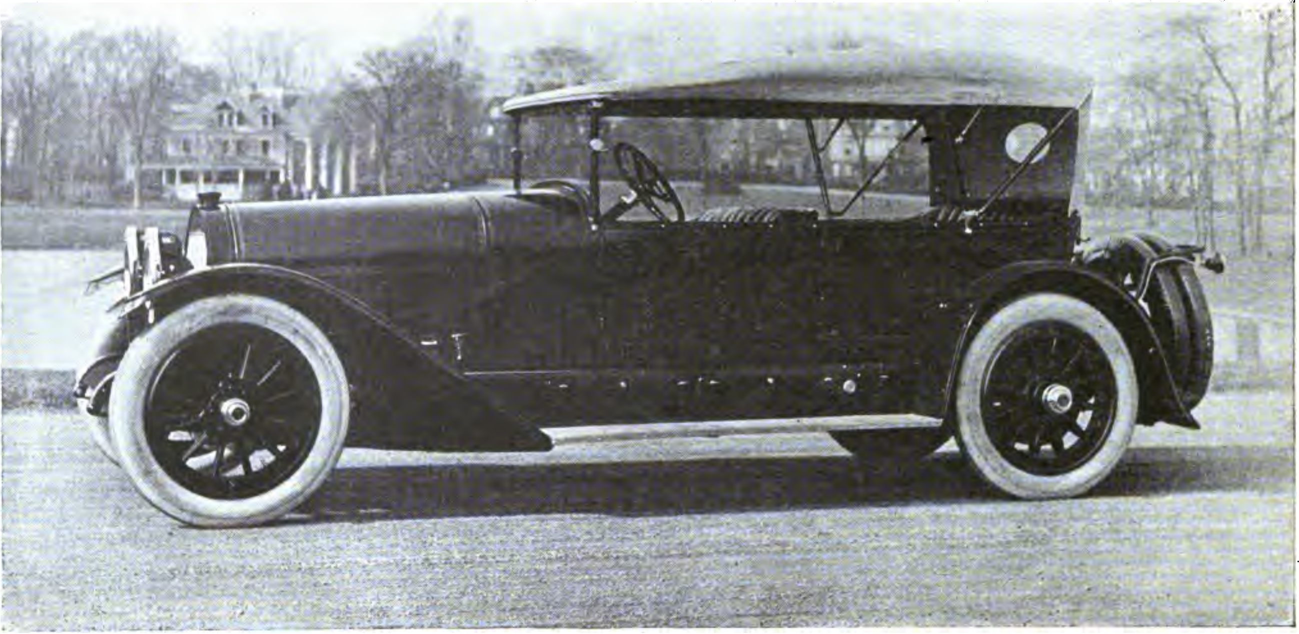

LOCOMOBILE FOUR-PASSENGER TOURING CAR
Courtesy of The Locomobile Company of America, Bridgeport, Connecticut

Automobile Engineering

A General Reference Work

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION,
CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND
MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION,
STARTING, AND LIGHTING SYSTEMS, GARAGE DESIGN
AND EQUIPMENT, WELDING, AND OTHER
REPAIR METHODS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE
HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

SIX VOLUMES

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CHICAGO
1920

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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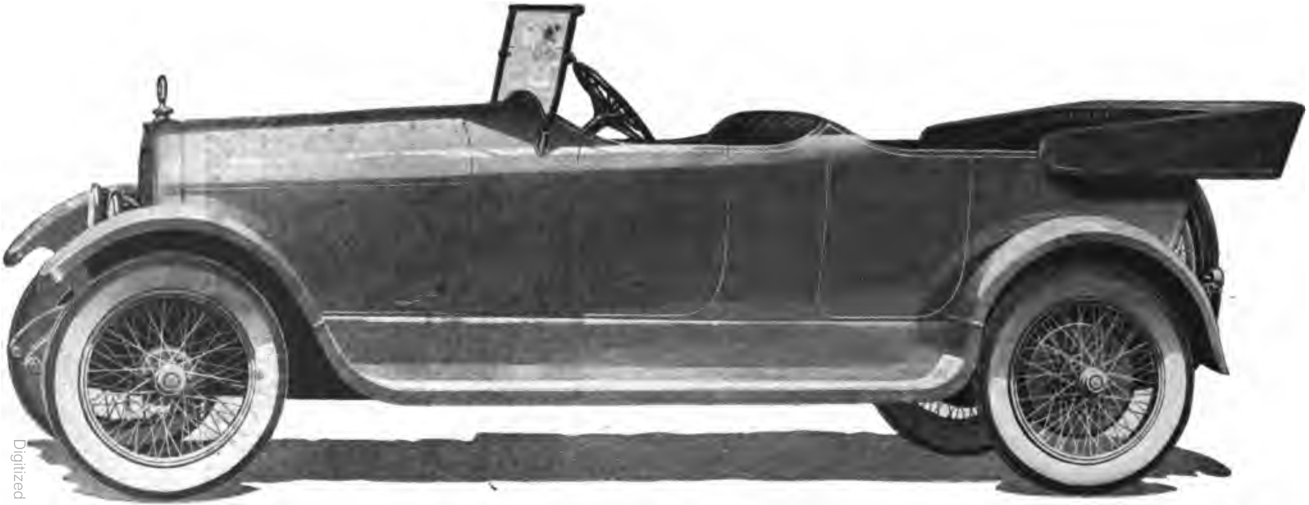

MARMON SEVEN-PASSENGER TOURING CAR
Courtesy of Nordyke & Marmon Company, Indianapolis, Indiana

HOLMES SEVEN-PASSENGER TOURING CAR
Courtesy of Holmes Motor Car Company, Canton, Ohio

Foreword

THE period of evolution of the automobile does not span many years, but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages, has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced driver, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. The refinements in the ignition, starting, and lighting systems have added greatly to the pleasure in running the car. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

❡ Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

❡ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place, but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the principal systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, and Garage Design and Equipment.

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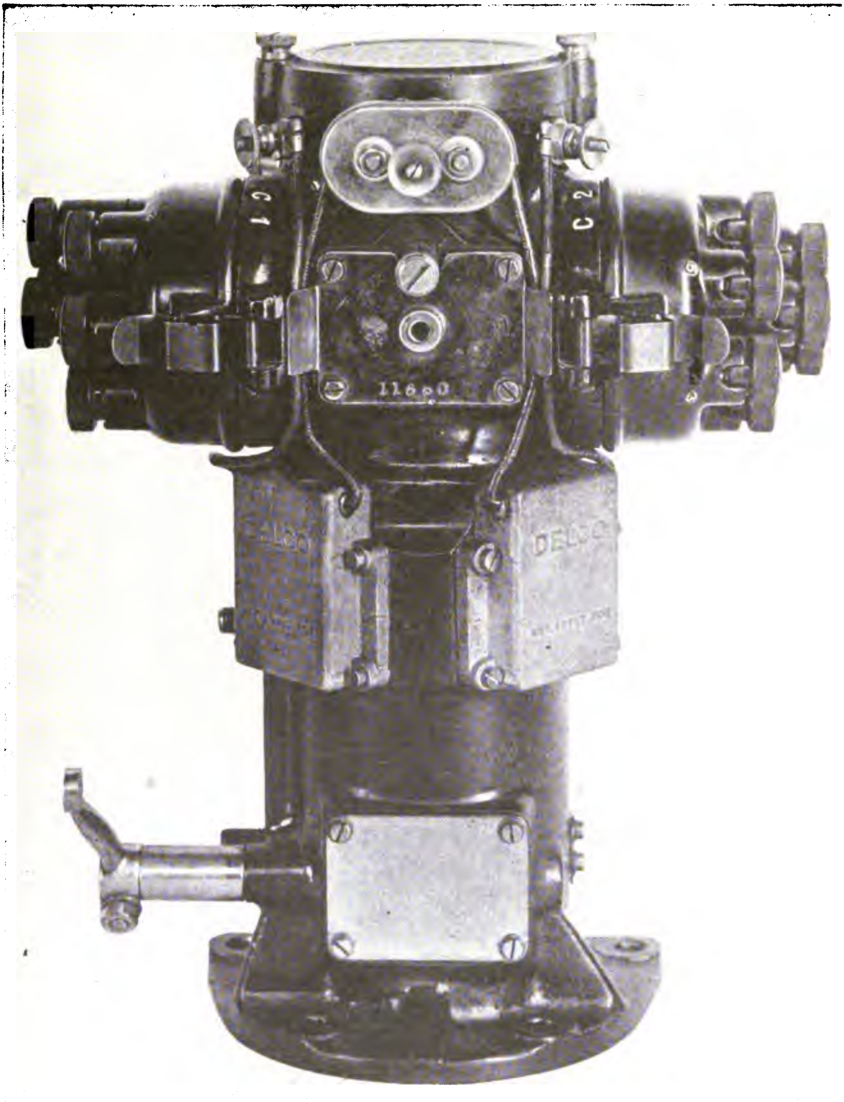

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ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART II

IGNITION

FUNDAMENTAL IGNITION PRINCIPLES

Faulty Ignition Cause of Much Early Trouble. More than half of the troubles encountered by the designers and the drivers of the early automobiles were the direct results of the extremely crude ignition systems at first adopted. With knowledge of gasoline-motor operation generally scant at that time, much of this trouble was attributed to causes entirely foreign to its real source or, on general principles, the motor was roundly "cussed" as a deep and unfathomable mystery. Subsequently it became plain that much of this inexplicable tendency to balk was due to the elusiveness of the electric current. Crude insulation and contacts, inherently defective spark plugs, and extremely wasteful current-handling devices, fed from a weak source, were the causes.

Distinctions between Low Tension and High Tension. A low-tension ignition system uses a low-tension current—i.e., the output of a battery or small generator, employed at the voltage at which it was produced, or, in other words, a primary current. A high-tension uses a high-voltage current produced by passing the output of the battery or other source of supply through a step-up transformer (induction coil). As this is taken from the secondary winding of the coil, it is sometimes referred

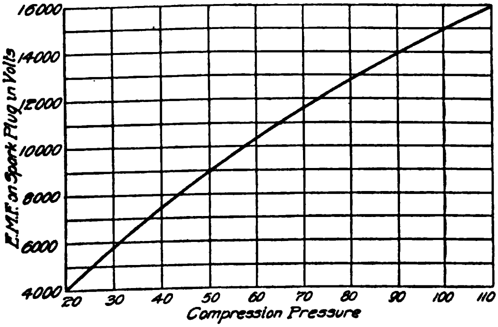

Fig. 37. Voltage Required to Force a Spark Across a .020-Inch Gap Under Different Compression Pressures

to as a secondary current It is the result of induction and is commonly termed a high-tension current owing to its great voltage or potential. The battery produced current of high amperage value at 6 to 8 volts, which after being passed through the coil became a current of microscopic amperage value at anywhere from 10,000 to 25,000 volts, according to what the designer of the coil thought was sufficient potential to produce a good spark, that is, to enable it to readily jump the gap in the points of the plug. The curve, Fig. 37, shows the voltage necessary to force a spark across a given distance in air under various pressures.

As the low-tension current will not jump an air gap, a further distinction between the two systems is the employment of totally different types of spark plugs. In the former, a mechanically operated plug, i.e., one that is held closed until the maximum current is passing through it and is then suddenly opened by being mechanically tripped by a cam or rod operated by the engine, is essential. Such a plug produces a spark that is immensely superior in heating value and, consequently, in igniting ability, to the usual thin spark that bridges the gap of a high-tension spark plug. But this most desirable quality is likewise quickly destructive of the contact points, necessitating frequent readjustment of the mechanically operated plugs. Moreover, the mechanical lag or time element of operation, due to the inertia of the numerous moving parts, rendered it difficult to make a low-tension spark plug suitable for a high-

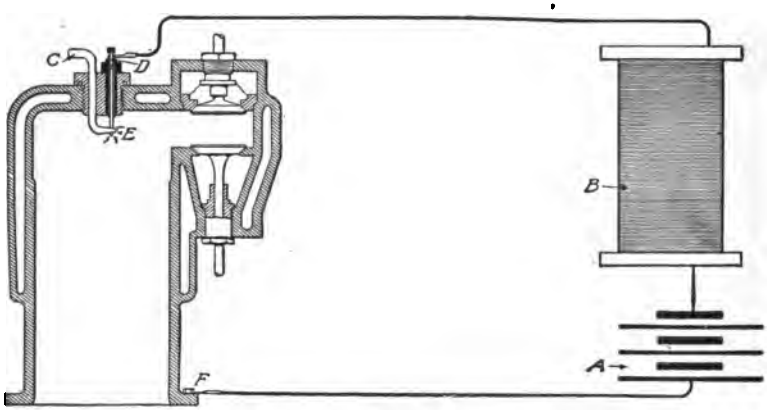

Fig. 38. Diagram of Low-Tension Ignition System

speed engine without resorting to the most expensive machine work, and much greater skill was necessary for their proper adjustment.

The shortcomings of the original high-tension systems were so glaring, however, that some of the most successful automobiles of earlier days were fitted with low-tension ignition.

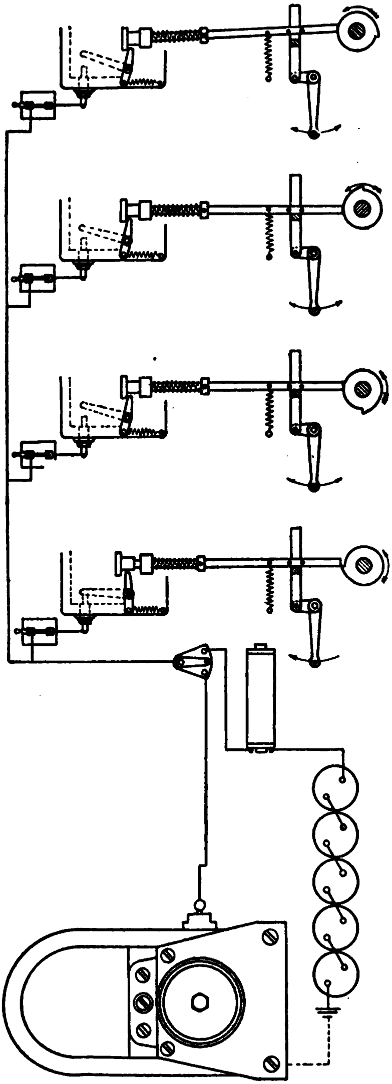

Fig. 39. Four-Cylinder Low-Tension Ignition System (*Horseless Age*)

Low-Tension System. Fig. 38 shows diagrammatically the essentials of a low-tension system for a single-cylinder motor, while Fig. 39 shows a complete low-tension system for a four-cylinder motor. The details of the operating mechanism and the plug are shown in Figs. 40 and 41. Referring to Fig. 38, *A* is the battery, *B* is a spark coil (a single coil which by its self-induction develops a high-voltage spark), and *C*, *D*, and *E* are the elements of a make-and-break device that is mechanically actuated at regular intervals by the motor itself to produce the sparks within the cylinder. As shown in the drawing, the circuit is completed by grounding the wires from one side of the battery on the cylinder base, or any other portion of the machine, as at *F*. In this figure *D* is a small insulated plug entering the interior of the cylinder, usually through one of the valve caps, while *C* is a movable arm (see also Fig. 40), that makes and breaks contact with *B*, at the point *E*, when it is given a slight rocking movement. For the best results this rocking movement must be very sharp and rapid, in the nature of a snap, and it must, of course, be correctly timed to occur in proper relation to the moment when the spark is required. (See also Fig. 41.)

The chief advantage of low-tension ignition is its immunity from troubles caused by short-circuiting by leakage of the current through poor insulation or across moistened terminals. This led to its almost universal employment on motor boats for a number of years, but it has since been generally abandoned even for marine use so that it is now only to be found on stationary engines, the low rotative speeds of which make it practical. So far as the automobile is concerned, the low-tension system is only of historical interest as it is already several years since it was wholly discarded.

High-Tension System. High-tension ignition systems are based on the fact that when a sufficiently high potential is impressed upon a current of electricity, it will leap an air gap or other break in the circuit of a width dependent upon the potential or voltage itself. In bridging such a gap, the current becomes visible in the form of an arc, flash, or spark, depending upon its duration and intensity, and it will readily ignite a gasoline or other gaseous fuel mixture Its

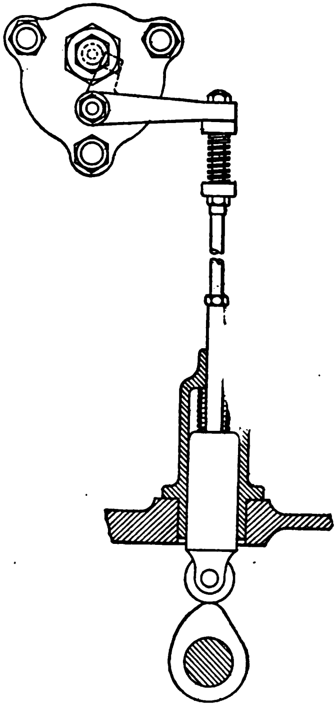

Fig. 40. Make-and-Break Mechanism

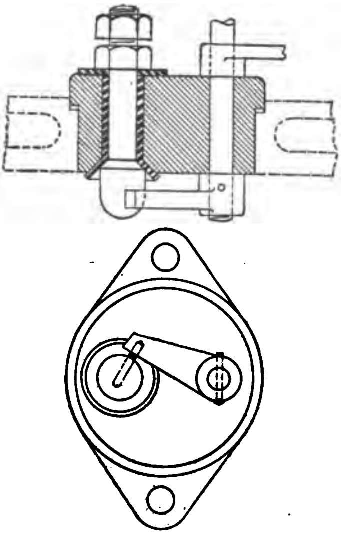

Fig. 41. Low-Tension Spark Plug (*Horseless Age*)

very ability to do so, however, was one of the most prolific sources of trouble in the early days, as the designer's conception of the insulation required to conduct such a current without grounding or short-circuiting was far from approaching the reality.

The essentials of a high-tension system are shown diagrammatically in Fig. 42. *A* is the source of current, usually a battery in earlier days, as indicated by the conventional sign, placed in a primary circuit that also includes the contact maker *C*, the primary winding of the coil *B*, and the vibrator *G*. The contact maker *C* is positively driven by a connection with some revolving part of the motor, so that it makes contact at the exact time ignition is required in each cylinder.

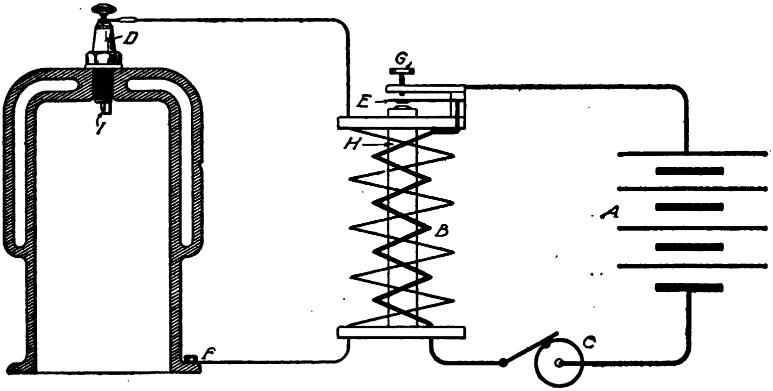

Fig. 42. Diagram of High-Tension Ignition System

With a system of the type described, when contact is made the first result is attraction of the vibrator blade *E* by the magnetized core *H* of the coil. This, by drawing *E* away from the contact screw *G*, at once breaks the primary circuit again, and this demagnetizes *H*, with the result that *E* again springs into contact with *G*. The effect of this is to cause a rapid series of current surges through the coil *B*, as long as the contact maker *C* maintains the contact.

Each time a surge of primary current passes through a coil, a secondary current of very high voltage is induced in the secondary circuit, which is grounded on the cylinder at *F* and connected at *B* with the spark plug. This plug, for high-tension ignition, has an open gap of about $\frac{1}{32}$ inch at *I*, across the resistance of which gap the current will jump, because of its high tension. Ignition is thus effected by a rapid succession of sparks across *I*.

This briefly describes what may be termed the rudiments of a high-tension ignition system and the diagram shows their relation to one another. Of course, this simply has reference to a single-cylinder motor. For each extra cylinder in an ignition system of the type illustrated, there is another contact point on the timer and another coil. The timer or contact maker is sometimes referred to as an interrupter, though this is not technically correct as its function is first to close the circuit.

SOURCES OF CURRENT

Up to about 1905, batteries were universally relied upon in this country for ignition work, the only exceptions to this being a few high-priced imported cars, some of which had magnetos operating low-tension systems with the so-called make-and-break spark plugs, while one or two, notably the Panhard, was equipped with the Eisemann magneto, designed to operate a non-vibrator coil. The writer imported the second of these magnetos to be brought into this country in the latter part of 1902, but the principles of its operation were so little understood, despite the fact that the magneto had been used in hand-ringing telephones for a generation, that automobile designers were frankly skeptical regarding it, and only the few electrical men then in the industry had the slightest conception of its possibilities. In fact, Mr. J. M. Packard, then head of the Packard Company, was the first man out of dozens to whom it was shown to realize what the magneto meant to automobile ignition.

CHEMICAL SOURCES OF CURRENT

Primary Batteries. In the face of the advent of the magneto (1902), the majority of American designers preferred to stick to the battery, usually the dry cell. The term dry cell is really a misnomer, since a cell of this type consists simply of a zinc element constituting the case of the cell, a carbon element centered within this, and an electrolyte composed of a moist paste of suitable chemicals. The top of the cell is commonly sealed with pitch or wax compound to prevent the moisture from evaporating, and if by any chance the cell does become really "dry", its usefulness is then at an end.

Defects of Dry Cells. The chief defect of the dry cell is that it is an "open-circuit" battery, that is, the circuit is normally open and when closed for a brief period the cell will produce a heavy current, at a low voltage, i.e., 1½ volts on the average. But to enable it to do so, the time of contact must be brief and the periods of rest frequent. Otherwise, the cell becomes "polarized". The hydrogen generated as the zinc element passes to the carbon element in such volume as to completely cover and insulate it from the active material of the cell, consisting of a solution of sal-ammoniac and water. The use of a depolarizer, usually manganese dioxide, prevents this to a certain extent, but not sufficiently to avoid having the current output of the cell fall off very rapidly if the contact exceeds a few seconds. But as soon as the circuit is broken again, the hydrogen is rapidly dissipated and the cell is said to recuperate. It was the marvelous ability of the dry cell to recuperate rapidly after having been run down to a point where it no longer produced sufficient current to pass a spark at the plug, that led to so much dissatisfaction and to such a misunderstanding of the gasoline engine in the earlier days. With the extremely wasteful contact makers then used, a set of cells would run an engine satisfactorily for an hour or so, then it would begin to miss firing badly and soon stop. Inspection would reveal no sign of current. If a new battery were installed, the engine would again run satisfactorily, and the motorist usually decided that the old cells were "dead". If, however, the inspection consumed ten or fifteen minutes, the battery recuperated and upon being cranked the engine again ran, only to repeat the performance a short time later.

Liquid Batteries. The dry cell is, of course, one form of primary battery, this term being used to distinguish it from other forms in which the exciting chemicals are in liquid solution. Few attempts have been made to employ the latter type of battery for automobile ignition, due to the violent agitation of the liquid which would necessarily ensue from the vibration and jolting. The Edison-Lalande cell and a few others of similar character, in which the charging chemicals were supplied in convenient units ready for quick replenishing when the battery "died", were tried in isolated instances but never met with general application, except on the motor boat, where the Edison-Lalande cells have been widely used.

Storage Cells. The construction and advantages of the storage cell as well as its operation and handling are detailed at length in the section on "Electric Vehicles". Due to its ability to provide a very much greater supply of current, it soon displaced the dry cell on all except the then lower-priced cars. While it represented a great improvement, the wastefulness of the contact maker and of the coil vibrators proved too much of a drain on even the storage battery, and it was accordingly displaced by the magneto. Since the general adoption of the latter, batteries have been wholly discarded except as a source of starting current, for the magneto does not generate sufficient current at a low speed to make it possible to start the motor without "spinning" it, which calls for considerable manual effort. Magneto practice is given in a succeeding section.

VOLTAGE AND SPARK CONTROL DEVICES

Changes in Ignition Methods. Up to a few years ago, it was generally considered that the magneto practically represented the ultimate type of ignition current generator and that batteries would never play anything but a secondary rôle. Small direct-current dynamos had been tried in a number of instances, chiefly prior to the advent of the magneto, but they were not then sufficiently developed for this form of service and proved quite as unreliable as the dry cell. The magneto was entirely dependable, made possible much greater speeds, and had few shortcomings, none of which were of a serious nature, so that its position was deemed impregnable. This was prior to the successful development of electric-lighting dynamos on the automobile, and more particularly the combined lighting and starting systems which are now in such general use.

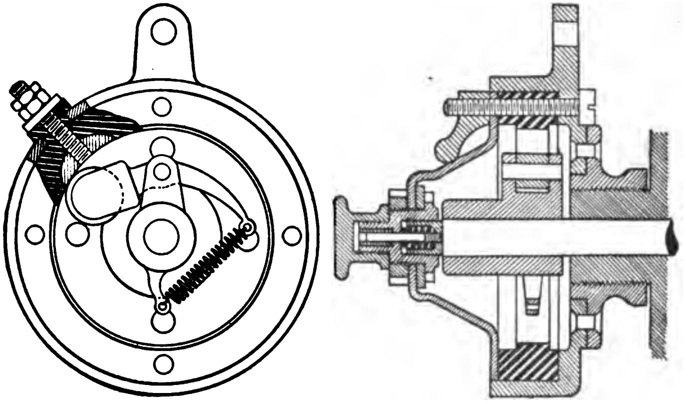

Fig. 43. Roller Contact Timer (*Horseless Age*)

The latter, in conjunction with improved forms of contact makers, has been responsible for bringing about a reversion to former practice with improved equipment.

Contact Makers or Timers. *Roller Contact Timer.* It was largely due to the crudity of the timing device that so much difficulty was experienced with early ignition systems. As the term indicates, the timer closed the circuit through the coil at exactly the moment necessary to produce the spark in the cylinder ready to fire. But the long wiping or rolling contact usually employed was so wasteful of current that it quickly exhausted even a storage battery. Fig. 43 shows a roller contact timer. The coil vibrators were another serious source of loss.

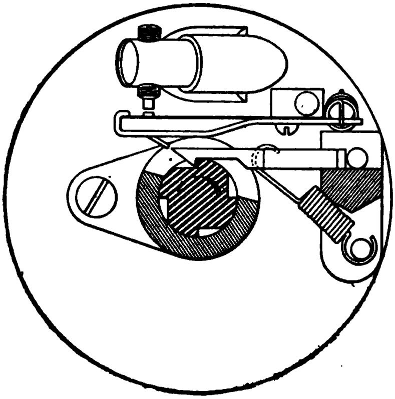

Fig. 44. Atwater-Kent Interrupter
Atwater-Kent Manufacturing Works, Philadelphia, Pennsylvania

Atwater-Kent Interrupter. The difficulties with roller contact led to the adoption of a totally different principle embodied in the Atwater-Kent interrupter, Fig. 44. This affords an exceedingly brief contact with an abruptness of the making and breaking of the circuit that is not secured with any other device. The effect is to produce a strong current surge and a heavy spark, but of the briefest possible duration.

The advantage of the brief duration is that great current economy is realized. The fact that only one spark is required for each ignition is an important contributing element to this economy.

With the Atwater-Kent interrupter, embodied in a distributor termed the "Unisparker", it is possible to run a car much further on a set of dry cells than could formerly be done with a storage battery, two to three thousand miles on four or five dry cells being nothing uncommon. This has led to the development of other devices along similar lines, and, with the unfailing source of current now provided by the lighting dynamo and the storage battery which forms part of the system, battery ignition has been raised to a level where it is now almost the equal of the magneto. But before making further mention of that phase of the subject, it is necessary to refer to the coil in order to give a clear understanding of the matter.

Coils and Vibrators. *Function of the Coil.* Mention has already been made of the function of the induction coil or transformer in stepping up the voltage of the current in order that it may bridge the gap in the spark plug. A coil is also employed in connection with a low-tension system, but it is simply a single winding on an iron core which intensifies the current by what is known as self-induction. Though it raises the voltage by what may be termed the accumulation and sudden release of electrical energy acting in conjunction with a magnetized core, due to the sudden making and breaking of the circuit, it is not an induction coil as that term is ordinarily employed.

As shown by Fig. 42, the latter has two distinct windings, one of a few turns of comparatively coarse wire and the other of many thousand feet of exceedingly fine wire, with high-grade silk insulation. After completing the coil, consisting of two superimposed windings and an iron-wire core passing through their center, it is placed in a wood box which is filled with melted paraffine wax which, upon solidifying, greatly enhances the resisting power of the insulation to breakdown, due to the great difference in potential between various parts of the secondary winding. To set up an induced current in the secondary winding, the primary circuit must be quickly opened and closed.

Necessity for Vibrator. The breaking of the primary circuit is accomplished by the use of a vibrator, a typical form of which is illustrated at *E*, *G*, and *H*, Fig. 42. This consists simply of the thin blade of spring steel at *E*, provided with an armature at the free end to intensify the attraction of the coil *H*, and adjacent to the adjusting screw at *G*, by which the distances between the contact points can be accurately set. In addition to these elements it is usual to provide a screw adjustment for increasing or reducing the tension of the vibrator blades.

Contacts in the best vibrators are made of platinum, or, better still, of platinum-iridium alloys, which are very hard as well as extremely resistant to the very high, though brief and localized, temperatures of the small arcs that form across the terminals each time the contacts are separated. In cheaper coils, German silver, silver, and other metals often are much used for contact points, but the only advantage of these over platinum or platinum alloys is their lower price.

Complication of Multi-Vibrator. A vibrator coil is necessary for each cylinder, each coil being energized as the timer passes over the contact corresponding to it, thus putting it in connection with the battery at the moment that particular cylinder is to fire. Fig. 45 shows a four-unit coil, i.e., for a four-cylinder motor. However, the coil cannot act before its core becomes "saturated", that is, thoroughly magnetized, and it must then pull its armature down against the tension of its spring, so that there is both an electrical and a mechanical lag, or, in other words, an appreciable amount of time elapses between the moment the circuit is closed by the timer and that at which it is again broken by the vibrator to cause the spark in the cylinder. A delicate adjustment is most sensitive and minimizes the lag besides economizing on current, but it is difficult to maintain. A stiff adjustment, on the other hand, will remain operative for a longer time, but its greater inertia makes the motor sluggish in action while the current consumption is increased several times over. Despite the use of platinum contact points, the heat of the spark is such that the latter burn away rapidly, necessitating frequent adjustment. As it is next to impossible to adjust four or six vibrators so that they will operate uniformly, it will be apparent why the vibrator coil was given up as soon as the magneto demonstrated that it was not a mystery beyond the understanding of the average motorist. The vibrator coil is accordingly obsolete and but for the fact that its existence has been extended by the Ford, it would probably be unknown to the majority of present-day motorists.

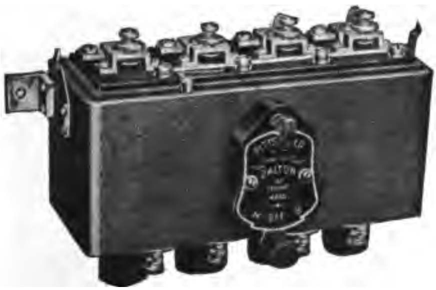

Fig. 45. Pittsfield Multi-Vibrator Coil
Courtesy of Pittsfield Spark Coil Company, Dalton, Massachusetts

Master Vibrator. To overcome the shortcomings of the four-unit vibrator coil, it is necessary to add a fifth coil. The latter is fitted with an especially sensitive and well-made vibrator which takes the place of the four vibrators on the original coils, so that the extra coil is termed a *master vibrator.* In operation, all four of the original vibrators are screwed down hard so as to make a permanent connection, and the fifth coil is connected in the primary circuit so that the action of its vibrator breaks the circuit in the primary of each one of the coils in turn. It is accordingly only necessary to adjust a single vibrator, and regardless of whether this adjustment be good or bad, it is uniform for all four cylinders so that they fire with the same timing. But at the best, the arrangement is only a makeshift as the vibrator coil long ago ceased to have any legitimate excuse of existence on the automobile.

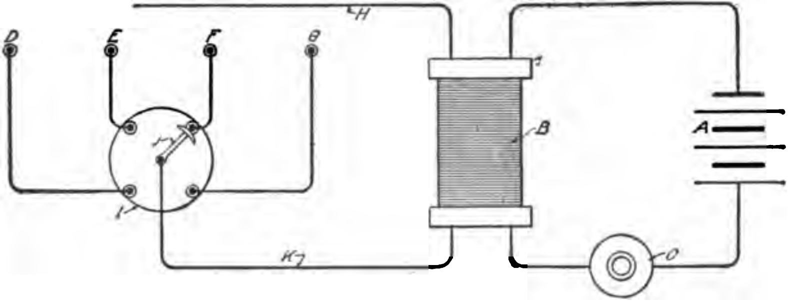

Fig. 46. Wiring Diagram of Non-Vibrator High-Tension System

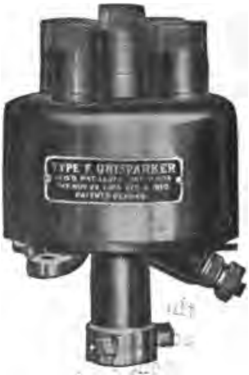

Fig. 47. Atwater-Kent Distributor

Non-Vibrator Coil. As the term indicates, this is simply an induction coil minus the vibrator. But instead of using four coils, as with the vibrator type, a single coil is employed, and a distributor is inserted in the secondary or high-tension circuit. The essentials of such a system are shown by Fig. 46, a battery being indicated as the source of current. The timer *C* is driven by the camshaft of the motor so that the battery circuit is successively closed and opened in the usual firing order of the cylinders, four contacts being made for each two revolutions of a four-cylinder four-cycle motor. The contact is of sufficient duration to permit the coil to "build up", i.e., to have its soft iron core become thoroughly magnetized, and is then quickly broken. At the instant that the latter occurs, the finger *J* of the distributor is passing the contact of the cylinder *F* to be fired. The timer and distributor must accordingly be driven synchronously, so that the contacts in both occur simultaneously. This is accomplished by combining them in a single unit, as shown in Fig. 47, illustrating the Atwater-Kent "Unisparker", or as in the various types of magnetos illustrated further along.

Limitations of current supply having been overcome by the adoption of the magneto or the storage battery kept charged by the lighting dynamo, non-vibrator coils are usually wound to a higher resistance than the old vibrator coils, so as to produce a current of higher tension in the secondary. As this type of coil requires no adjustment, it is generally installed horizontally with its face flush with the dash, and on this face is mounted the switch giving three control points, i.e., neutral, battery (for starting), and magneto. The Remy dash coil, Fig. 48, is a typical example.

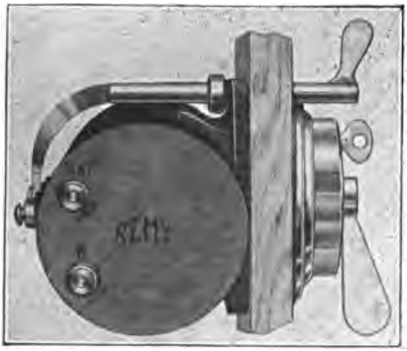

Fig. 48. Remy Single Non-Vibrator Coil Showing Method of Installation

Distributor. This is simply a modification of the timer, designed to handle the high-tension current, or to distribute it to the different plugs. It takes the place of the multi-unit coil in which an independent coil is employed for each cylinder. Owing to the high voltage of the secondary current, actual contact is not necessary in a distributor, a small gap or clearance presenting no obstruction to the passage of the high-tension current, so that wear at this point is avoided. In the earlier types, a brass arm passing close to contact points, or sectors embedded in hard rubber, was usual. Carbon brushes making contact against the disk by means of light springs, were subsequently adopted and are now commonly used. As the carbon is very hard and its contact surface becomes glazed by the friction, the wear is practically negligible. The complete wiring of a distributor system is shown in Fig. 46. *H* is the ground or common-return connection of the secondary circuit and *K* is the connection to the distributor *I*, from which the high-tension current is distributed by the arm *J* to the spark plug leads *D, E, F*, and *G*.

Condenser. The condenser is technically known as an electrical "capacity" in that it has the ability to absorb a quantity of electricity proportioned to the area of its conducting surfaces and to the nature of the dielectric employed. This property is utilized to absorb the excess current passing at the moment the primary circuit of the ignition system is opened by a vibrator, thus bringing about a quick cessation of the current flow and preventing the destructive arcing or burning that would otherwise occur at the contact points. The charge thus absorbed is immediately returned to the circuit in the form of a discharge, when the points come together again and a higher potential value is impressed upon the current. A condenser consists of conducting surfaces placed between insulating surfaces, known as the dielectric. For ignition work, the conducting surfaces are sheets of thin tinfoil cut with conducting tabs which project beyond the ends of sheets of paraffined paper on which the tinfoil is placed. Between each two sheets of paraffined paper is placed a sheet of tinfoil, the latter being arranged so that the tabs project at alternate ends, Fig. 49. The paraffined paper overlaps the tinfoil all around to the extent of an inch or more to prevent a discharge over the edges of the sheets. The capacity of the condenser depends upon the number and the size of the sheets of tinfoil and the thinness and the character of the dielectric separating them; and, when a sufficient number have been assembled, the projecting tabs at each end are riveted or clamped together and a flexible wire lead connected to each. It is then connected in multiple with the vibrator, and, in the case of a coil is inserted in the containing case of the latter and further insulated as well as held in place by having molten paraffine poured around it so as to fill the space. A condenser practically eliminates sparking at the contact points and is also used with the contact breaker of a magneto.

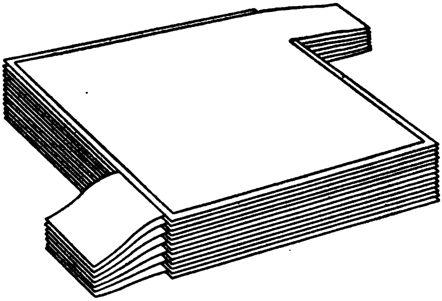

Fig. 49. Sketch of Condenser

Spark Plugs. No small part of the trouble experienced with early ignition systems was due to the defective design of the spark plugs employed. Where an over-rich mixture is delivered by the carbureter, i.e., one containing too much gasoline in proportion to the air, a certain amount of the carbon is unburned and remains in the cylinder in the form of soot. This is greatly increased by an excess of lubricating oil finding its way into the combustion chamber. The heavier carbons of this burn to the same consistency and are also deposited on the piston head, cylinder walls, valves, and other exposed surfaces in the form of a flint-hard coating. The end of the spark plug receives its share and, as the carbon is an excellent conductor, the plug is accordingly short-circuited, so that the current, instead of jumping the gap between the points, takes a path of lower resistance across the carbon-coated insulating surfaces.

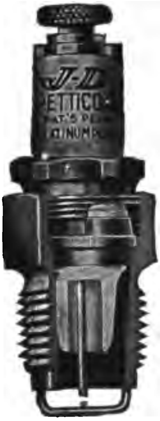

Fig. 50. J-D Spark Plug

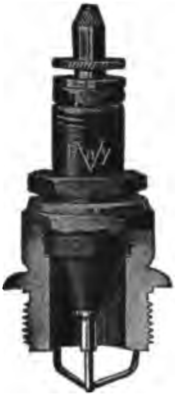
Fig. 51. V-Ray Spark Plug

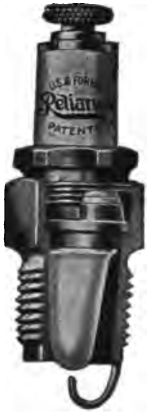

Fig. 52. Open-Point Spark Plug

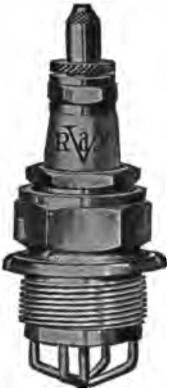
Fig. 53. Multi-Point Spark Plug

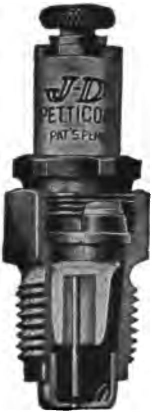

Fig. 54. Chambered-End Spark Plug

Fundamental Requisite. The spark plug is the "business end" of the ignition system and no matter how elaborate or efficient the essentials of the latter may be, its successful operation is governed entirely by that of the plug. As originally designed, the insulating material filled the shell at the sparking end, affording a direct path for the current as soon as this small surface became covered with carbon. Failure was accordingly frequent, it being nothing unusual to have to clean such a plug in less than fifty miles of running. To overcome this, a recess was allowed between the insulation of the central electrode and the outer shell. This simple expedient constitutes a basic patent (Canfield) under which all spark plugs are manufactured. Porcelain, mica, or artificial stone is used as the insulating material, the first-named being most generally employed. This is made in various forms, as shown by the sections, Figs. 50 and 51, and it will be noted that the smaller diameter of the insulated electrode in the center greatly increases the area of the surface of both shell and porcelain that must be coated with carbon before a path is formed for the current.

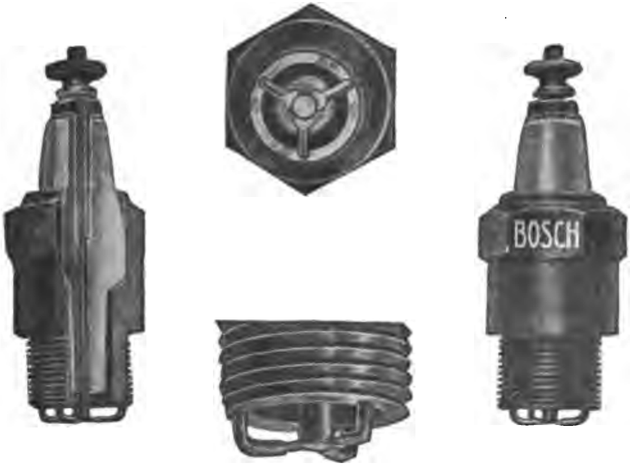

Fig. 55. Bosch High-Tension Spark Plug

Electrode Arrangement. Practice also varies considerably in the arrangement of the electrodes, taking the form of open points as in Fig. 52, a bridge as in Fig. 50, or a number of points as shown in Figs. 51 and 53. In some instances, the central electrode is enclosed in a chamber, the gas entering through a small hole in the shell, as shown in Fig. 54. Considerable advantage is claimed for the type of plug having a plurality of gaps, the number usually being three, as shown in Fig. 55, or four as in Fig. 53. It is more theoretical than actual, however, as the current always takes the shortest path and the bridging of any one of the gaps by a particle of conducting material, such as carbon, short-circuits all of them.

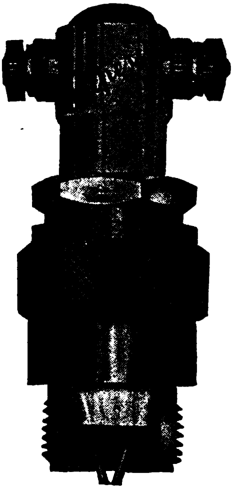

Fig. 56. Series-Type Spark Plug

Series Plugs. As shown in the various wiring diagrams, the shell of the plug is one of the electrodes and forms a part of the circuit by being screwed into the cylinder, the latter constituting part of the common ground return for both the primary and the secondary circuits of all ignition systems. Experiment has shown a slightly increased power resulting from the simultaneous occurrence of two sparks in different parts of the combustion chamber of the cylinder, especially with the T-head type of cylinder in which the two plugs can be located in the oppositely placed valve ports. This is termed double-spark ignition and the type of magneto designed for this purpose is described in the section on "Magnetos". To obtain the same result with the standard ignition circuit designed to produce but one spark in each cylinder, what is known as a "series" type of plug has been developed. One of these is shown in Fig. 56. In this the spark occurs between two central electrodes, as shown, the shell not forming a connection with the cylinder. The lead from the distributor is attached to one of the binding posts of this plug and a second wire connected to the other binding post is led to a standard type of plug, thus completing the circuit and placing both plugs in series so that a spark occurs simultaneously in both. By means of an attachment as shown in Fig. 57, this type of plug can be used with a grounded return, the arm shown connecting the shell in the circuit. As the majority of motors now in use have L-head cylinders, and even at the best the advantage gained is very slight, the use of series plugs has not a great deal to recommend it.

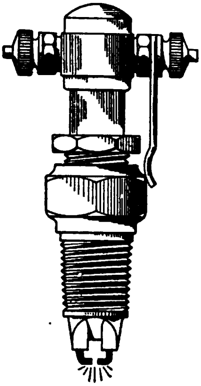

Fig. 57. Method of Converting Series Plug

Magnetic Plugs. With a view to overcoming the defects of the mechanically operated make-and-break plug as used on low-tension ignition systems, an automatic plug was developed. As shown by the section, Fig. 58, this is simply a solenoid *A* and plunger *C*, the latter being held in contact at *D* by a spring *B*. The current passing through the winding *A* lifts the plunger and the spark occurs at *D*. The remainder of the system consists of a low-tension magneto or other source of current supply and a timer. Such plugs have been used to some extent on stationary engines, but have not proved practical on the automobile motor, as the high temperatures drew the temper of the plunger spring and often burned out the insulation of the winding.

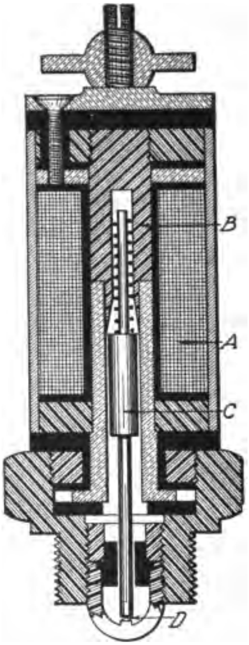

Fig. 58. Low-Tension Magnetic Spark Plug

Priming Plugs. For low-priced motors, such as the Ford, which have no pet cocks or compression-release cocks on the cylinders, a spark plug combined with a pet cock, such as that shown in Fig. 59, can be had. These are usually known as "priming" plugs in that they permit of priming the cylinder with gasoline to render starting easy in cold weather.

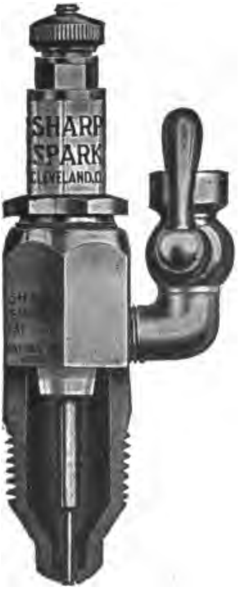

Fig. 59. Priming Type Spark Plug

Waterproof Plugs. Ignition systems, on motor-boat engines in particular, are apt to suffer short-circuiting from spray or dampness, though this often happens on the automobile as well in heavy rainstorms. To guard against this a so-called waterproof type of plug is provided. The precaution usually takes the form of a hood of hard rubber or other insulating material placed over the connection, as shown in Fig. 60.

Plug Threads. European practice has standardized a straight-threaded plug, the thread itself usually being of fine pitch. A plug of this kind is screwed home on a gasket of copper and asbestos or of the latter material alone, which is relied upon to prevent leakage. Foreign types are usually referred to as "metric" plugs, as the thread dimensions are based on the metric standard. As developed at first in this country, all spark plugs were made with an "iron-pipe" thread. This has a taper of three-fourths inch to the foot and the plug is screwed into the cylinder as far as the taper will permit, no other provision being made to hold the compression. As this is a crude expedient, adopted chiefly because of its cheapness, and the metric standard is not employed here, an S.A.E. standard plug has been developed along the same lines, both the plug diameter and the thread itself being made somewhat larger than those used abroad.

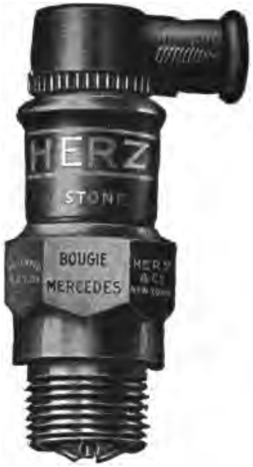

Fig. 60. Spark Plug, with Waterproof Connections

Hydraulic Analogy in an Ignition System. A comparison of the workings of an ignition system with the action of an hydraulic system having similarly related parts will serve to make clear the operation of the former. It must first be borne in mind that a high-tension ignition system consists of a source of current; an interrupter, or method of automatically breaking the circuit of this current supply, timed with relation to the revolution of the engine crankshaft; a condenser to suppress the arc at the interrupter contacts; a transforming device, or induction coil, to transform a current of comparatively high amperage at a low potential to one of high voltage; a device for distributing this high-tension current to the spark plugs, also timed with relation to the crankshaft; and the spark plugs themselves.

Current. The electric current in the ignition system may be represented by water flowing in a pipe from a source of supply which puts it under pressure, corresponding to the storage battery. A certain amount of frictional resistance must be overcome by the water in flowing through the pipe and this is equivalent to the electrical resistance of the wiring in the ignition circuit. The rate of water flow in the pipe corresponds to the current in the coil, and the inertia of the water to the inductance of the primary winding of the induction coil. Now, if the flow of water be suddenly stopped, there will be an enormous increase in the pressure, due to the inertia of the water. This effect, known as *water hammer,* is commonly noticed in the larger sizes of pipes carrying water under considerable pressure. It corresponds to the great increase in the pressure, or voltage, which takes place when the flow of current in the primary of the ignition circuit is opened suddenly by the interrupter. This is due to the inductance in the coil. A quick-closing valve in the water system would accordingly correspond to the timer contacts which interrupt the current in the primary of the induction coil.

Office of Condenser. There is one peculiar tendency of timer contacts which must be mentioned here to make the analogy more complete. Unless protected by a condenser, they are apt to burn away very rapidly, due to the arc produced by the current at the moment of separation. (This is also true of the contacts of the battery cut-out and of the regulator employed in connection with starting and lighting systems; the condenser does not eliminate this tendency to burn away but reduces it to a minimum.) This failing on the part of the timer contacts would correspond in the hydraulic system to a valve with a very thin edge which would be liable to bend under the sudden rise in pressure before it is fully closed. In the case of both systems, therefore, it is necessary to arrange for some protection, and a condenser is supplied for this purpose in the ignition system.

In the hydraulic system, it takes the form of a surge chamber, as shown in Fig. 61. This chamber has an elastic diaphragm centrally placed in it, and the chamber itself is shunted, or connected, around the valve in the same manner as the condenser is connected to the contact points. When the valve begins to close, this surge chamber relieves the pressure to some extent during the operation of closing the valve and so protects the thin edge of the valve from bending. After the valve is fully closed, there is, of course, no further danger of its being bent over. In the electrical system, the condenser supplies similar protection, reducing the voltage at the timer contacts at the moment of separation and keeping this voltage reduced until they are fully open, thus preventing the current from bridging the gap, or *arcing.* Once the contacts are fully separated, the low-tension current cannot jump the air gap, so that there is no further danger of their burning.

Transformer. In order to utilize the pressure produced by the sudden closing of the valve, it is necessary to provide some transforming device, such as a pressure chamber. This is illustrated in Fig. 61, and it will be noted that it is of a much larger diameter than the pipe. As the pressure in the chamber and the pressure in the pipe will both have some unit value (measured in pounds per square inch), the total pressure on the piston will be to the pressure in the pipe as the area of the piston is to the area of the pipe. By the use of a pressure chamber of large diameter, compared to that of the pipe, a very considerable force is applied to the piston, but the distance it will travel is very slight. (To simplify matters, the weight of the piston is disregarded in this connection.)

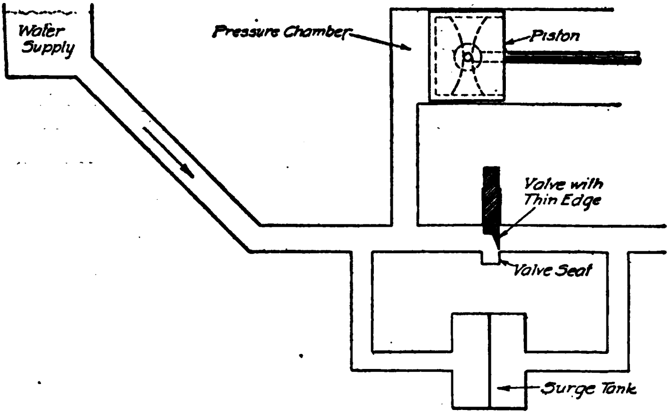

Fig. 61. Diagram Showing Hydraulic Analogy of Ignition System

It is likewise necessary to provide a transforming device in the ignition system, and, in the case of both magneto and modern battery systems, this is the induction coil, having a relatively large number of turns in the secondary winding and a comparatively small number of turns in the primary. (In the earlier battery system, a vibrating coil is used for each cylinder and there is no distributor, while in the true high-tension magneto, the coil is part of the armature winding.) Just as in the hydraulic system the increased area of the piston is responsible for the increased total pressure on it, so the large number of turns in the secondary of the coil give the very high voltage required to enable the current to bridge the air gap at the spark plugs.

This high voltage is accompanied by a very small amount of current, just as in the hydraulic system the greatly increased pressure on the piston produces but a very slight movement of the latter. This rise in the voltage and decrease in the current can be made clear by a brief explanation. By the principles of induction, a current flowing in the primary coil will induce a current in the secondary coil. The energy of these currents in watts is equal to the electromotive force in volts times the current in amperes. Now, as the transformer cannot create electrical energy, the energy of the transformed current must equal the energy of the current before it is transformed, barring a small loss within the transformer. This means that if the voltage of the current is raised from 6 volts, say, in the primary to 6000 volts in the secondary (that is, made one thousand times greater), the amperage of the primary current must be correspondingly reduced from 2 amperes, say, to .002. In other words, the product of the current and electromotive force must be always the same before and after transformation.

INDUCTION SOURCES OF IGNITION CURRENT—MAGNETOS

Owing to the failure of either dry cells or storage batteries to supply sufficient current to operate the wasteful contact devices at first employed, mechanically driven current generators were adopted. American practice at first favored the small, high-speed direct-current dynamo, but as proper regulating devices had not then been developed, it was not successful, chiefly because its speed range was so limited. Few of these little dynamos generated sufficient current at less than 1200 r.p.m. to ignite the charge in the cylinder, so that at slow speeds they would not run the motor. If run much faster, they burned out and were accordingly abandoned.

Working Principle. The magneto is simply a small dynamo in which the fields consist of permanent magnets, instead of electromagnets, the cores of which only become magnetic when a current is passed through their windings. Hard steel, particularly when alloyed with tungsten, retains a very substantial percentage of its magnetism, after having been once magnetized by contact with a powerful electromagnet. Its retaining power is further increased by placing a "keeper", or armature, across the poles, or ends. The advantage of a permanent field for magneto use is that it is at its maximum intensity regardless of how slowly the armature is revolving so that a good spark is produced at very low speeds; while its initial value cannot be exceeded no matter how fast the machine is run, so that the armature winding cannot be burned out. All magnetos generate an alternating current so that when used with a coil there is no necessity of frequently making and breaking the circuit, as is done by the vibrator of a coil handling direct current, the alternate surges of current from zero to maximum of opposite polarity producing the same effect more efficiently.

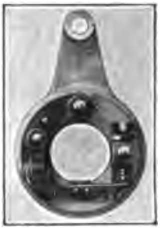

Fig. 62. Remy Magneto Contact Breaker

Low-Tension Magneto. A low-tension magneto is nothing more or less than the simple instrument which formed part of the thousands of telephones of the hand-ringing type still to be found in rural districts. Built with more powerful magnets and wound to give a greater current output at a lower voltage, it was employed in connection with low-tension ignition systems. A magneto of this type is illustrated by Fig. 39. As the mechanically operated make-and-break plugs are timed, the magneto is simply revolved continuously without reference to the motor timing, the current being constantly delivered to the circuit through the usual collector ring and brushes. Magnetos

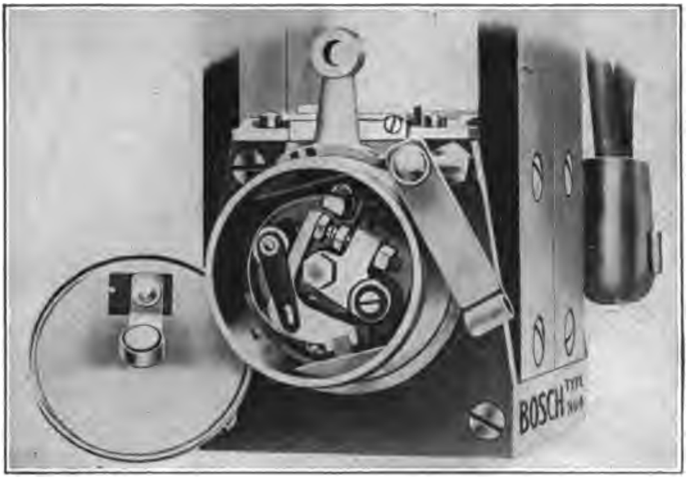

Fig. 63. Contact Breaker of High-Tension Magneto (Bosch)

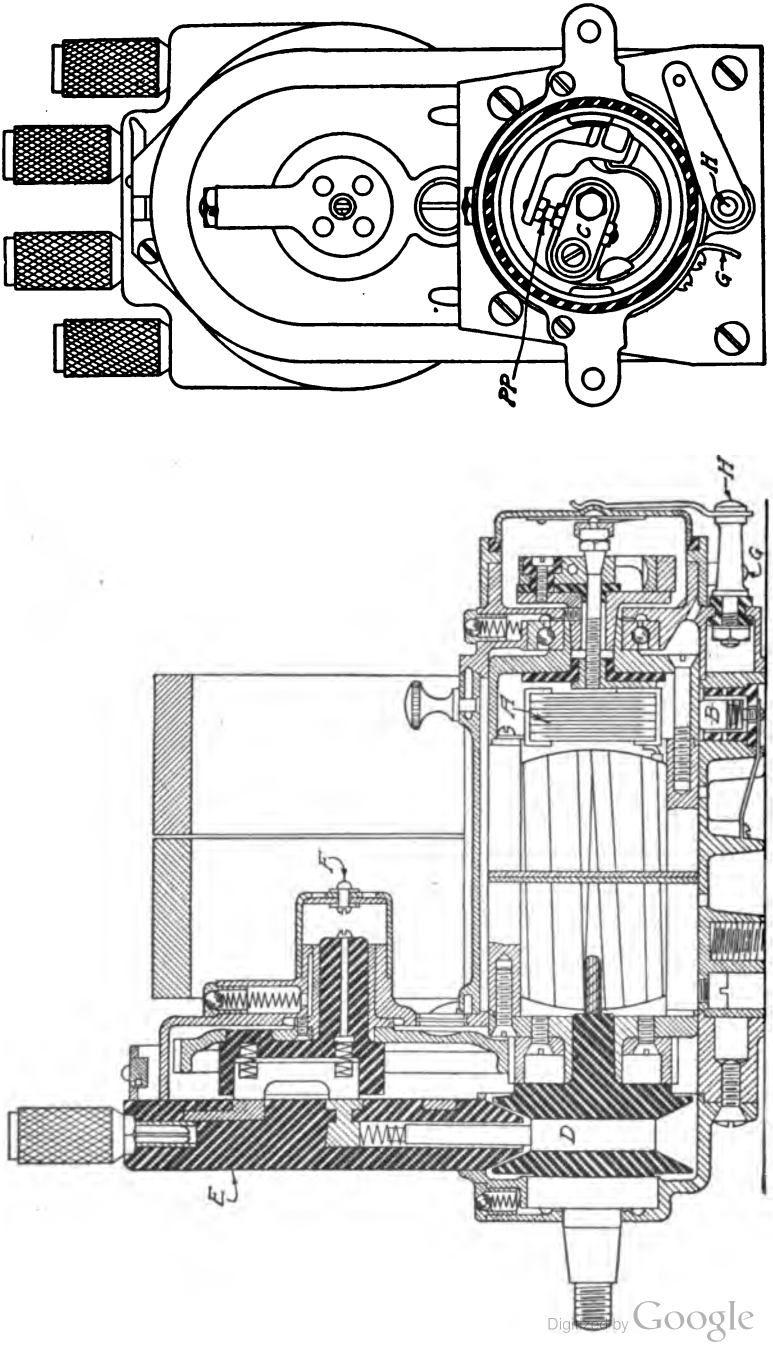

Fig. 64. Sectional and End Views Through High-Tension Magneto (*Horseless Age*)

of this type are still used to a greater or less extent on large, slow-speed stationary engines.

High-Tension Magneto. Essentially all magnetos are the same: that is, they have a permanent magnet field and a two-pole armature. In what may be best identified by terming it the *true high-tension type*, there are two windings on this armature, a primary winding of comparatively coarse wire in which the current is generated, and a secondary winding of fine wire, the same as an induction coil. A magneto of this type is timed with the motor according to the number of cylinders, being driven at crankshaft speed in the case of a four-cylinder motor and at one and a half times crankshaft speed in the case of a six. In addition to the usual current-collecting device, it is equipped with a contact breaker or interrupter, such as that shown in Fig. 62, which is part of a Remy magneto. Fig. 63 shows the same essential of a Bosch light-car type magneto. Except at the point in the revolution at which the spark is to occur in the cylinder, the armature circuit is normally short-circuited upon itself. This permits it to "build up", so to speak; that is, as the armature poles come within the most intense part of the field, the current in the armature winding reaches its maximum value and, at this moment, the contact points of the breaker are opened and a strong current is induced in the secondary winding. As the distributor runs synchronously with the contact breaker, the circuit to one of the plugs is closed at the same time the spark occurs at it.

Description of True High-Tension Type. A sectional view of a true high-tension magneto is shown in Fig. 64. In this the primary and the secondary windings on the shuttle armature are entirely separate to insure better insulation. These windings are not shown in section in the illustration, the usual insulating tape winding being indicated on the armature. Twice during every revolution of the armature, the primary circuit is opened at the platinum points *PP* of the circuit breaker, the interruption occurring substantially at the moment when the primary current is at its maximum. From the primary winding, the current is conducted to the stationary member of the contact breaker *C* through the terminal *B*. *A* is the condenser. One terminal of the secondary winding is connected to the end of the primary winding, as in a coil, and the other connects with the high-tension collector ring *D*, from which it is conducted through a carbon brush to the brush of the distributor above it for distribution to the four brass segments in the distributor plate *E*. These segments are connected to the four terminals shown extending above the magneto in the end view at the right and from them the usual high-tension cables are led to the plugs. The distributor is driven from the armature shaft of the magneto through 2 to 1 gearing so that it only makes one revolution for two turns of the crankshaft in the case of four-cylinder four-cycle motor, as in the latter but two explosions occur per revolution. To vary the time of occurrence of the spark in the cylinders, the contact breaker may be turned through part of a revolution by means of a rod and linkage fastened to one of the extensions of the contact breaker box, as shown in the end view. This connects with the spark timing lever on the steering wheel and, to stop the action of the magneto, it is only necessary to move this lever to the extreme retard position, which brings the spring *G* in contact with the bolt *H* and short-circuits the secondary winding.

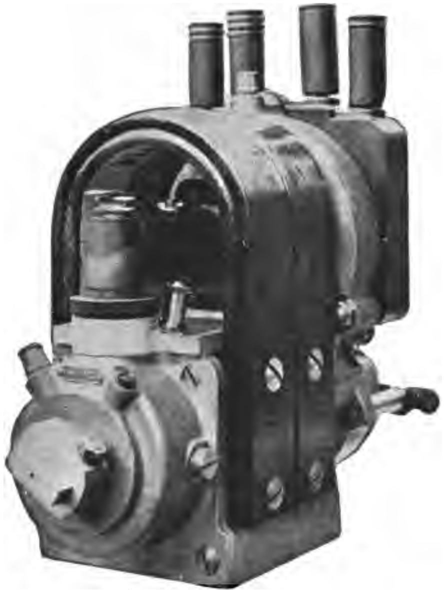

Fig. 65. Contact-Breaker End, Nilmelior Magneto

The magneto, Fig. 65, differs from the section, Fig. 63, chiefly in detail. The vertical plug just back of the contact-breaker box incorporates the safety gap.

Typical High-Tension Magneto Circuit. Fig. 66 is the wiring diagram for a high-tension system, using a true high-tension type magneto. *C* and *B* are the wires of the primary circuit, in which circuit there are also included, besides the current-generating coils of the armature, an induction coil built into the magneto, for raising the current tension, and a contact breaker *E*, which is carried on the same revolving spindle that bears the armature. The dotted lines indicate the ground return.

High-Tension Type with Coil. This is not actually a high-tension magneto, properly so-called, as it only generates a low-tension current, which is subsequently stepped up through a transformer or non-vibrator coil, but it is commonly so termed as it is always used in connection with a high-tension ignition system. In this case there is only a single winding on the armature and the current is led from the latter through the usual contact breaker and then to an independent coil, generally located on the dash. The condenser is combined with the coil, and from the latter the high-tension current is led back to the magneto to be distributed. Owing to its lower cost, this type of magneto is probably more generally employed, especially on medium-priced American cars, than any other.

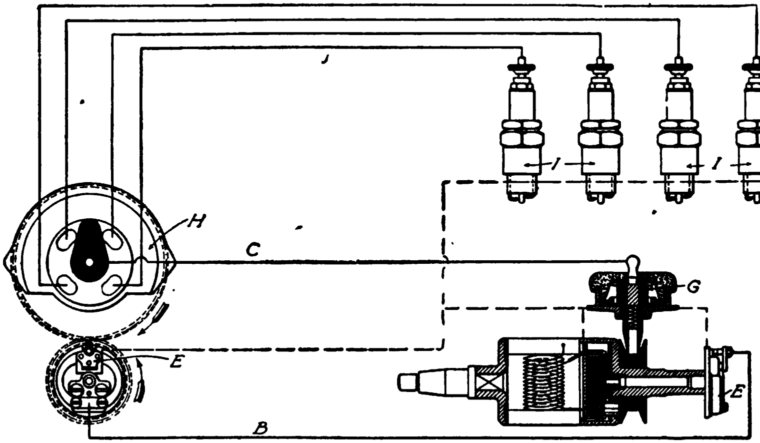

Fig. 66. Wiring Diagram of High-Tension Magneto System

Safety Gap. If the current induced in the secondary winding of an induction coil meet with a resistance in the outer circuit in which the coil is connected, greater than the resistance presented by the insulation of its own windings, it will puncture this insulation and the expensive coil will be ruined. The placing of such a resistance in the high-tension circuit occurs when the connection of a spark plug is removed from the plug terminal and is allowed to dangle in the air beside the motor and, unless this were guarded against, it would result in the breakdown of the ignition system. The precaution takes the form of a safety gap. This is an opening inserted in the circuit, and its length is based on the safe maximum distance that the coil can bridge in normally dry air. A safety gap of this kind is shown at *F* in Fig. 64. In the type of magneto just described above it is embodied in the coil. When an opening at any point in the high-tension circuit exceeds the length of this gap, the current takes the path thus provided, thus preventing the imposition of an excessive strain upon the insulation of the secondary windings.

Wiring Connections. For the actual operation of an induction coil, there is no necessity for any electrical connection between the primary and the secondary windings, the electrical energy being transferred from one to the other entirely by induction, i.e., through the intermediary of the magnetic lines of force which interlink both. However, for the sake of simplicity of external connections, the beginning of the secondary winding is usually connected to the end of the primary. Both the primary and the secondary circuits have a "ground return", which necessitates that one end of both the primary and the secondary winding of the coil be placed in positive metallic connection with the engine or car frame. By connecting the two windings, as mentioned, a single wire serves to ground both. The average coil, therefore, has only three terminals, i.e., one primary, one secondary, and one common ground connection.

On cars that are provided with magneto ignition alone, as is the case with French taxicabs and many other French light cars, there would be only two connections between the magneto and the coil, one primary and one secondary; one connection from the coil to a ground, as the motor or frame; and four connections direct from the magneto distributor to the spark plugs. This represents an ignition system reduced to its lowest terms of simplicity. As a matter of fact, it is even more simple in reality, as most French cars use the true high-tension type of magneto so that the four leads from the magneto to the plugs are the only external wires in evidence. Unless a magneto is in excellent condition, however—and the magnets lose their strength more or less rapidly under the influence of the heat and vibration—too much effort is required to start the motor. American manufacturers accordingly supply a battery for starting purposes, and on some of the high-priced cars this takes the form of an entirely independent battery ignition system, i.e., having a battery, coil, timer, distributor, and a separate set of spark plugs. It also constitutes an emergency system that may be resorted to in case of a breakdown of the magneto, but the latter is so rare and the cost and complication of the extra system are such that the latter is not generally used. Instead, the magneto coil, contact breaker, and distributor are utilized with the battery as the source of current.

Inductor-Type Magneto. Mention has been made in the introductory of the fact that if a coil of wire be moved so as to cut the lines of force of a magnetic field, an e.m.f. will be induced in the wire. If, instead of moving the wire, a magnetic flux be made to pass through it first in one direction and then in the other, the same result will be obtained, i.e., an alternating e.m.f. will be produced, and, if the wires be connected to an outside resistance, a current will flow. This is the principle of the *inductor magneto* which is so termed because the current is induced in its winding instead of being directly generated in the latter.

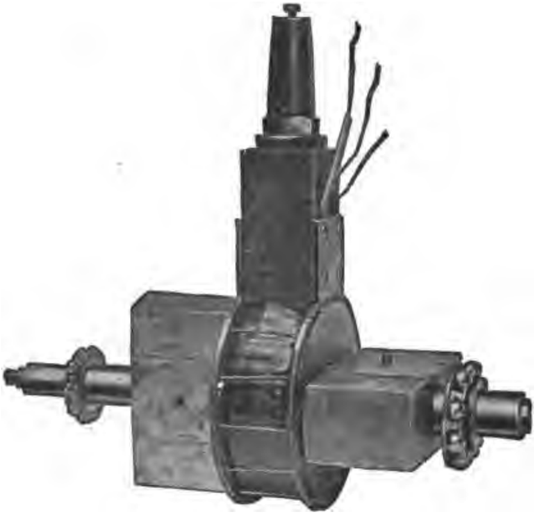

Fig. 67. Rotor and Winding of K-W Inductor Magneto
Courtesy of K. W. Ignition Company, Cleveland, Ohio

Typical Construction Details and Current Production. The magnetic field is produced by permanent magnets in the same manner as on other types of magnetos and a mass of laminated soft iron is rotated between the pole pieces while the winding is stationary. The moving element is termed the rotor, and this part of the K-W high-tension magneto is shown in Fig. 67. The stationary winding in the center is mounted on the shaft of the rotor and consists of a primary and secondary coil.

There is no mechanical or electrical connection between the windings and the rotor shaft, nor between the laminated blocks of the rotor and the windings. As shown in the illustration these are placed at right angles to one another and are riveted to the shaft. It will be evident that in the position shown in the illustration the right-hand member of the rotor will be bridging the pole pieces of the magnetic field; by giving the shaft a quarter turn the two rotor members will have their ends facing opposite poles of the magnetic field, thus completing the magnetic circuit through the center of the windings. Consequently, a current wave will be produced each time the rotor revolves through a quarter-turn, or 90 degrees, so that this inductor magneto produces four impulses per revolution instead of two as in the ordinary type having a wound bipolar armature of H form. Apart from the method of producing the current, the remaining essentials of the magneto are the same,

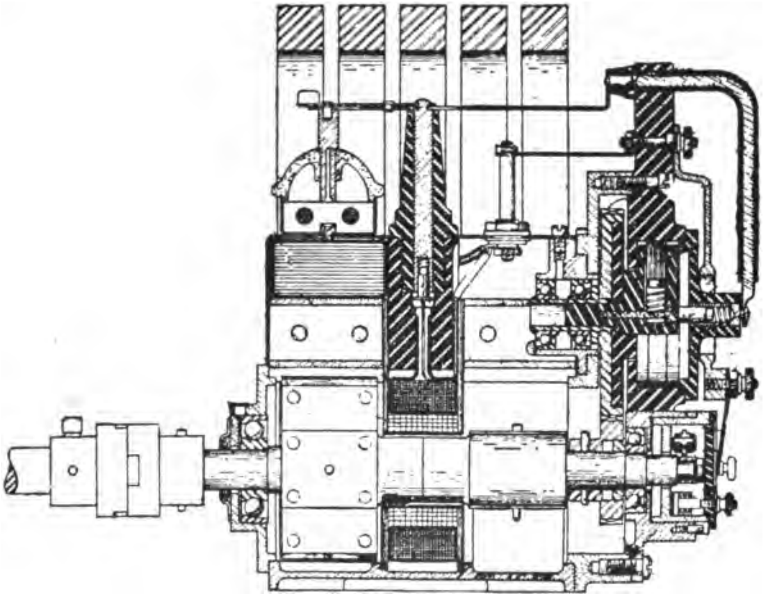

Fig. 68. Section through K-W Inductor Magneto
Courtesy of K. W. Ignition Company, Cleveland, Ohio

except that no collector brush is necessary as is the case where the current is generated in a revolving winding on an armature.

The details of construction of the K-W high-tension magneto are shown in Fig. 68. While, from an external view of the rotor, it apparently consists of two independent parts, it will be seen in the section that it is practically one piece, the connecting part passing through the center of the winding so that the magnetic circuit is completed through the latter. The primary winding, consisting of four layers of comparatively coarse wire, will be noted close to the rotor; just outside of this is the secondary winding of many layers of fine wire and from the latter the connection is carried upward to a horizontal strip of copper termed a bus bar. At the right, this bar connects with the distributor for the high-tension current; at the left it connects with the safety gap, directly beneath which is the condenser.

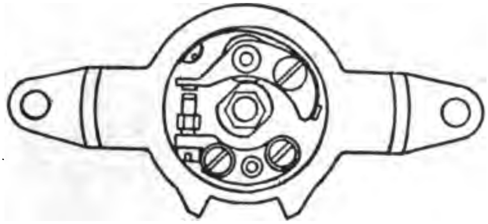

Fig. 69. K-W Interrupter

Timing. The magneto is timed by an interrupter operated by a cam on the rotor shaft in the usual manner; the details of this interrupter are shown in Fig. 69. As is the case with all ignition magnetos, these points remain closed, thus short-circuiting the primary winding, until the current reaches its maximum, and then are opened suddenly, thereby inducing a current in the secondary winding. The firing point of the magneto is just as the contact points begin to separate, as shown in Fig. 69, which is exaggerated to make this clear. At the same moment, the distributor arm is passing one of the segments connected to a spark plug, as shown in Fig. 70, the firing order of the motor in this case being 1, 2, 4, 3. While the magneto produces four waves per revolution, these are not necessarily all utilized; the cam (*c* in Fig. 70) opens the interrupter twice per revolution, giving two sparks for each turn of the crankshaft, as required by a four-cylinder four-cycle motor. In a four-cylinder two-cycle motor, a four-sided cam would be employed thus producing four sparks per revolution.

The letters on the illustration are: *A* contact breaker box; *c* cam;

P contact points of interrupter; *R* cam roller to lessen friction at that point; *B* distributor arm; *S* distributor segments; *RH* and *LH* referring to the direction of rotation, as either right hand—also termed "clockwise" or from left to right—and left hand, anti-clockwise.

Dixie Magneto. *Essential Elements; Circuits.* While based on the inductor principle, this differs from an inductor type of magneto in that the pole pieces themselves are revolved and they do not reverse their polarity as in the case of an inductor or an armature.

The rotating element of the Dixie is shown in Fig. 71; *B* is a brass block which prevents any magnetic flux flowing directly from *N* to *S*, which are the rotating pole pieces. The coil with its primary and secondary windings is placed directly above this rotating element, in the hollow of the magnets, as shown in Fig. 72. At the right in the same figure is shown the relation between the rotor, the magnets, and the coil. It will be noted that the core of the coil *C* bridges the stationary pole pieces *F* and *G* and that the shaft of the rotor passes through the magnets in a plane at right angles to that of the usual magneto. The reversal of the magnetic flux, with varying positions of the rotor, is shown in the right-hand sketch of Fig. 72, and in Fig. 73.

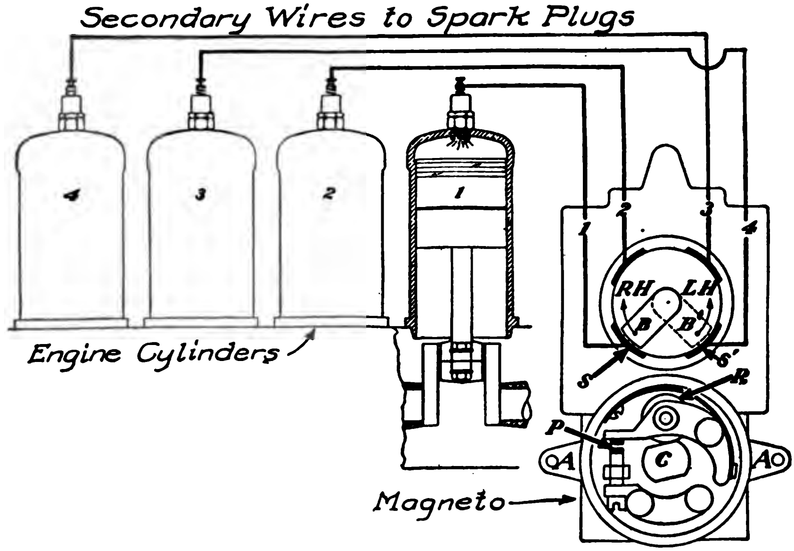

Fig. 70. Wiring Diagram for K-W Magneto Circuits

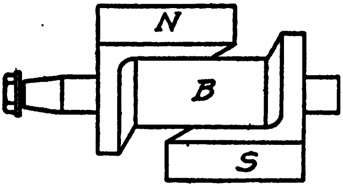

Fig. 71. Rotating Element of Dixie Magneto

The primary circuit of the Dixie is shown in Fig. 74; *A* being the core of the coil, *P* the primary winding, *R* the condenser, *X* and *Y* the points of the interrupter or contact breaker. The terminal *D* is a screw on the head of the coil, and the wire *Z* connects directly with the contact *Y* of the interrupter. Fig. 75 shows the details of this interrupter, the housing of which is attached to the mounting of the windings, while the details of the secondary circuit are shown in Fig. 76. *C* is the end of the high-tension, or secondary winding of the coil, which is connected to a metal plate *D* embedded in the hard-rubber end piece of the coil *A*. A small coil spring holds the connection *F* in contact with *D* and at its outer end *F* connects with *J* which is the distributor brush. The latter revolves, successively passing over the segments leading to the corresponding spark plugs.

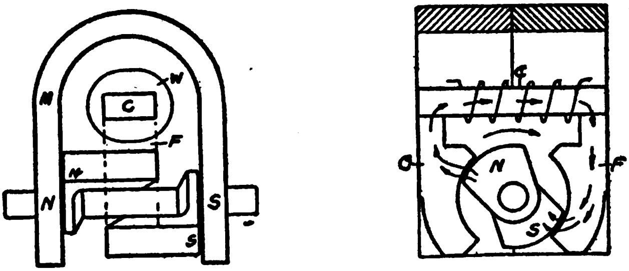

Fig. 72. Details of Dixie Magneto
Courtesy of Splitdorf Electrical Company, Newark, N. J.

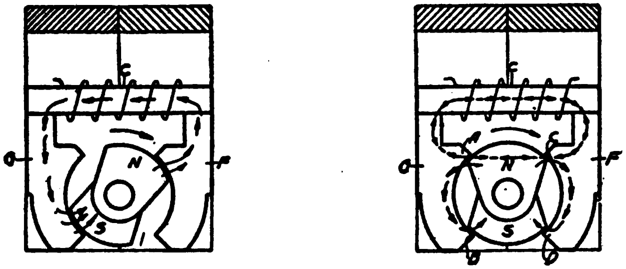

Fig. 73. Diagram Showing Reversal of Magnetic Flux in Dixie Magneto

But one of these segments is indicated by *L*, the dotted lines indicating the completion of the circuit through the ground connections.

Timing. As the contact-breaker box is attached to the mounting of the coil, the latter moves with it when the former is partly

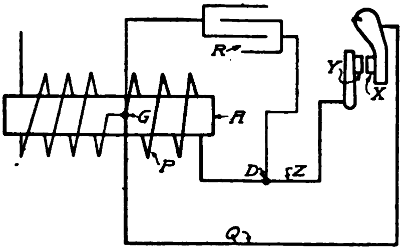

Fig. 74. Primary Circuit of Dixie Magneto

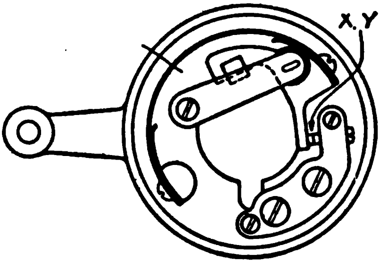

Fig. 75. Dixie Interrupter

rotated to advance or retard the occurrence of the spark in the cylinders, so that the opening of the contact points always takes place at the point of maximum current. This is shown diagrammatically in Fig. 77. As the contact points are opened by the revolution of the cam, it will be apparent that a movement of the mounting of these points with relation to the cam will alter the time at which they will operate. For example, assuming that the magneto is designed to run clockwise, moving the interrupter in the same direction as the rotation will cause the spark to occur later, as shown by the retarded position in the sketch. Moving the interrupter against the direction of rotation of the cam accordingly would cause the spark to occur earlier. The range of movement is approximately 15 degrees each side of the neutral point indicated by the horizontal position of the lever on the breaker box; the dotted lines show how the firing point may be advanced 15 degrees or retarded an equal amount. The lever in question is connected by means of linked rods to the spark lever on the steering wheel.

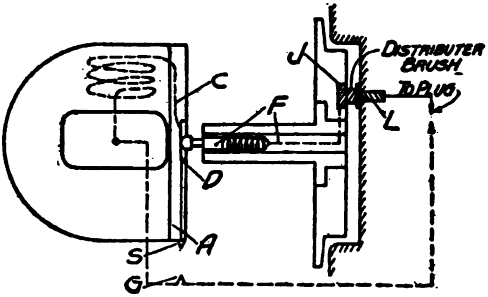

Fig. 76. Diagram of Secondary Circuit in Dixie Magneto

Magnetos for Eight-Cylinder and Twelve-Cylinder Motors. It will be evident that, regardless of the number of cylinders to be fired, the principles of current generation, transformation (to high tension), and distribution remain the same, so that a reference to the models of the Dixie for eight-cylinder and twelve-cylinder motors will suffice to cover the modifications required by the increased number of cylinders. To keep the speed of the magneto down, the rotor is provided with four poles instead of two, so that four impulses are generated in the windings per revolution. This permits of running the magneto at crankshaft speed for an eight-cylinder motor and at 1½ times crankshaft speed for a twelve-cylinder motor.

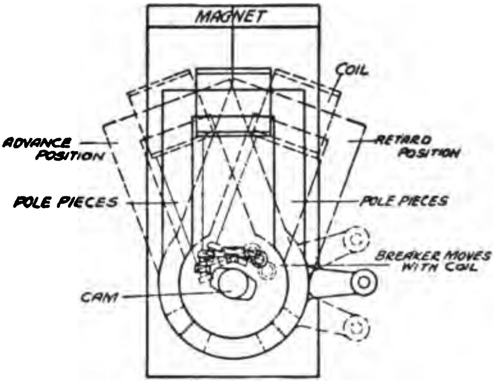

Fig. 77. Diagram Showing Method of Timing Dixie Magneto
Courtesy of Splitdorf Electrical Company, Newark, N. J.

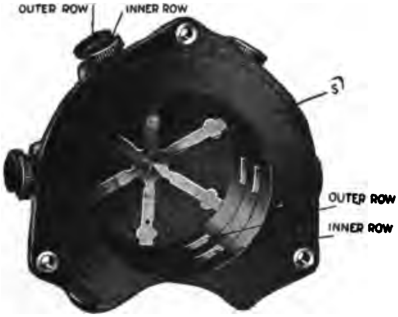

Fig. 78. Stationary Member of 12-Cylinder Splitdorf Distributor

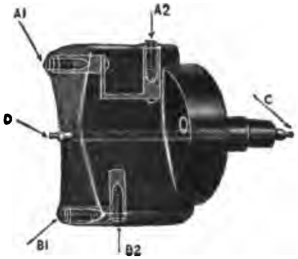

Fig. 79. Rotating Member of 12-Cylinder Distributor

Compound Distributor. The contact breaker opens every quarter revolution instead of every half revolution—a cam with four lifting faces being provided for this purpose—and the distributor is provided with twice as many segments and spark-plug leads as a magneto designed for four-cylinder or six-cylinder motors. But as the contact segments of the distributor must be sufficiently long to permit of the distributor brush being in contact with them, regardless of the point to which the ignition timing is advanced or retarded, it is impossible to place more than six contact segments in a circle without reducing the insulation between them to a point where there would be danger of the high-tension current jumping the gap and thus deranging the ignition. To avoid this a compound distributor is employed, i.e., two distributors are combined, but instead of being placed on a flat surface as in the magnetos for a smaller number of cylinders, the segments are spaced around the inner periphery of a hollow cylinder. Two radial contact brushes are carried by the revolving member of the distributor, each of which makes contact with one of the sets of segments. Fig. 78 illustrates the distributor itself, while Fig. 79 is the revolving member. The radial brushes *A*2 and *B*2 of Fig. 79 are electrically connected to contact brushes extending laterally (*A*1 and *B*1) from the revolving member. These brushes make contact alternately with the arms of a metal spider sunk flush in the end wall of the distributor, *S* in Fig. 78, with which the central pin of the distributor rotor *D*, Fig. 79, also connects. The high-tension current from the windings is fed to this distributor rotor through the spring brush contact *C*.

Path of Current. The path followed by the current is accordingly as follows: from the high-tension winding of the coil (not shown here) to the distributor rotor through the brush *C;* from brush *D* to the spider *S;* from *S* alternately through brushes *A*1 and *B*1 to the distributor segments representing the inner and outer row of spark-plug leads, through the brushes *A*2 and *B*2. Brushes *A*1 and *B*1 are so spaced that, when one is centrally in contact with an arm of the spider *S*, the other is midway between the second and third arms from the one with which contact is being made.

The relation of the various members of the Dixie magneto will be clear upon reference to the sectional view, Fig. 80, showing one of the four-cylinder models. The contact breaker or interrupter is at the left-hand end of the rotor shaft; just above the rotor itself is the coil, while to the left of this is the distributor.

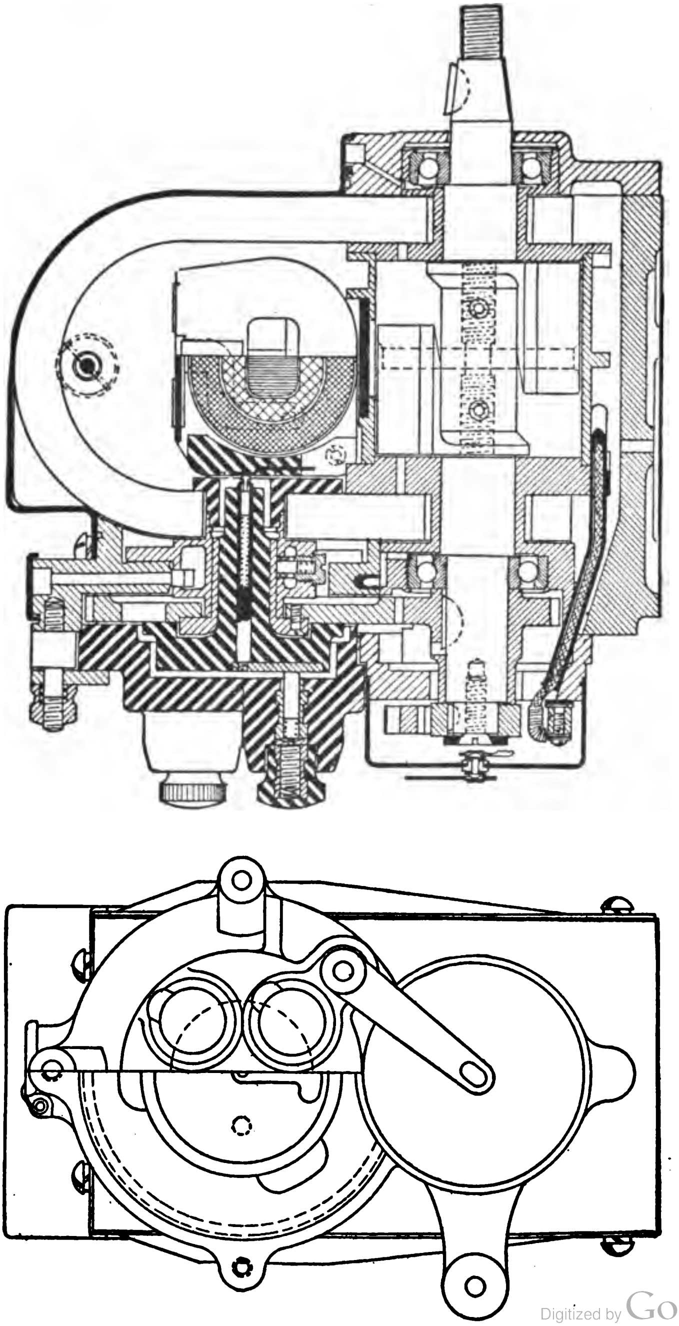

Fig. 80. End Elevation and Section of Dixie 4-Cylinder Magneto Showing Construction and Connections
Courtesy of "The Horseless Age"

IGNITION SYSTEMS

STANDARD TYPES

Dual Ignition System. *Bosch Type.* The dual type of ignition system uses one coil and one set of plugs with either the battery or the magneto as the source of current supply, the magneto contact breaker and distributor being common to both. Fig. 81 illustrates the connections of a dual system. Wire Number *1* is in the low-tension circuit and conducts the battery current from the primary winding of the coil to the contact breaker of the magneto. Low-tension wire Number *2* is the grounding wire by which the primary circuit of the magneto is grounded when the switch is thrown to the "off" or "battery" position. Wire Number *3* leads the high-tension current from the magneto to the switch contact, and wire Number *4* is the wire that carries the high-tension current from the coil to the distributor. Number *5* leads from the negative terminal of the battery to the coil, and the positive terminal of the battery is grounded by Number *7*; a second ground wire, Number *6*, is connected to the coil terminal. The press button on the switch cuts in the battery circuit which includes a special vibrator on the coil which is employed simply for "starting on the spark"; i.e., when a charge of gas is left in the cylinders and the crankshaft has stopped with

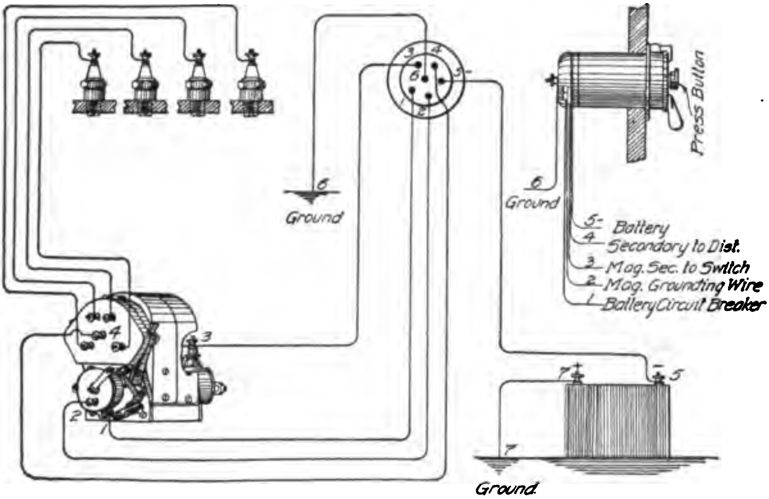

Fig. 81. Wiring Diagram Dual Ignition System

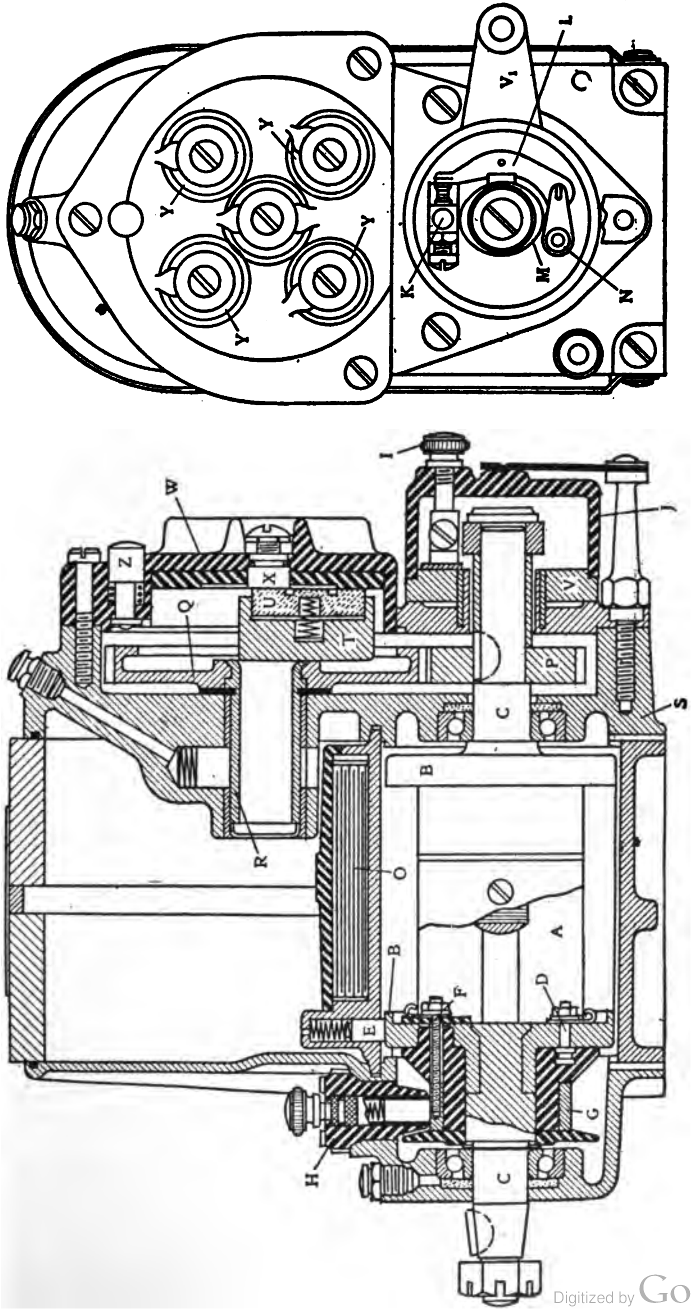

Fig. 82. Section and End Elevation of Remy Dual Type Magneto
Courtesy of "The Horseless Age"

the pistons in the proper position for firing the next one in order, a spark in that cylinder will frequently start the motor.

Remy Type. Prior to the general adoption of electric lighting and starting systems, the dual type of ignition system was almost universally employed on the lower and medium priced cars, many thousands of which are still in service. The Remy magneto, a section and end elevation of which are shown in Fig. 82, is typical of the class used for this service. The armature *A* is of the *H* or shuttle type, of laminated construction fitted with cast bronze heads *B*. It carries a single winding, one end of which is grounded by connecting it to the rear bronze head at *D*, the ground connection being further insured by the carbon brush *E*, pressed against the head by a spring. The other end of the armature winding is connected through an insulated stud *F* to the collector ring *G* from which the current is taken by a carbon brush in the holder *H*. From this brush a low-tension cable runs to the induction coil mounted on the dash.

The other primary terminal of the coil is connected to the terminal *I* on the breaker box at the right-hand end of the magneto. This terminal, which extends through the breaker-box cover *J* of insulating material, forms an integral part of the contact screw *K* which carries one of the contact points of the interrupter. The other contact point is mounted on the free end of the lever *L*, pivoted at its lower end and provided with a fiber contact block bearing against the cam *M* carried on the armature shaft. The contact screw *K*, interrupter lever *L*, and its stud *N* are all supported on the metal plate *V* forming the interrupter base. This plate is supported on a lateral projection from a disc secured to the forward end plate *S* of the magneto and is provided with the radial arm *V*, which is connected by jointed rods to the spark timing lever on the steering wheel. This permits of moving the breaker box through part of a revolution with relation to the cam on the armature shaft to advance or retard the time of ignition, as explained later under Spark Timing. The interrupter lever *L* is grounded to the frame of the magneto through the stud *N*. The condenser *O* is placed in the armature cover plate and has one terminal connected to the stationary contact screw *K* and the other terminal grounded, so that it is shunted or "bridged" directly across the interrupter and serves to minimize the spark or arc caused by the opening of the contacts. The condenser is sometimes combined with the coil.

Details of Typical Distributor. Apart from slight variations in detail, the following description of the distributor is typical of all magneto distributors. At its right-hand end, the armature shaft, Fig. 81, carries the steel pinion *P*, which meshes with the bronze gear *Q* having twice the number of teeth. Rigidly mounted in the bronze distributor gear *Q* is a carbon brush *U* carried in the holder *T*. This brush is pressed by its spring against the inner surface of the insulating cover of the distributor *W*, in which are embedded a central contact block *X* and four or six (according to the number of cylinders) contact blocks *YY*, equally spaced about a circle. At their outer ends these contact blocks carry terminals for the attachment of the high-tension cables. As the distributor revolves it makes contact with the central block *X* and all of the blocks *YY* in succession.

Since the distributor gear *Q* has twice as many teeth as the armature pinion, it makes but one revolution for every two turns of the crankshaft (four-cylinder motor) and of the armature, the latter being driven at crankshaft speed. As the four-cylinder motor fires only twice per revolution, it is only necessary for the distributor to make one complete turn for every two revolutions of the crankshaft. The distributor is so geared to the armature shaft that it operates synchronously with the interrupter, i.e., whenever the contacts of the latter separate to open the magneto armature circuit and permit the current to flow through the primary of the coil, the brush *U* is on one of the contact blocks *Y*. The exact moment of opening is governed by the setting of the timing lever, but the distributor brush *U* is made of sufficient width to cover the contact block throughout the whole timing range. A feature of this model of the Remy magneto is the timing button *Z* fitted into the distributor cover, to facilitate the adjustment of the timing of the magneto to the motor. Most magnetos have to be disconnected from the driving shaft to accomplish this. This button is normally held out by its coil spring. If the button is pressed in and the armature shaft is then turned, the plunger of the button will drop into a recess in the distributor gear. Then the engine must be turned over by hand until the piston of cylinder No. 1 is exactly at the upper dead-center position at the beginning of the power stroke, and while the crankshaft of the engine and the armature shaft of the magneto are in these relative positions, the magneto driving gears must be meshed and the magneto gear secured on the tapered end of the armature shaft by means of a Woodruff key which is held in place by a bushing and nut, as shown in the sectional view, Fig. 82.

Typical Wiring Diagram. Fig. 83 is a wiring diagram of a typical dual-ignition system that illustrates the connections in greater detail than in the case of the Bosch system. The switch shown just below the induction coil has three positions: "OFF" (central); "BATTERY" (left); and "MAGNETO" (right). When the switch is on the BATTERY contact, the current flows from the battery through the switch and the primary winding of the coil to the interrupter, and completes the circuit by means of the ground connection of the latter and the coil. The secondary current is distributed in exactly the same manner as when the armature of the magneto is supplying the low-tension current. As the interrupter has its contacts closed, except for the momentary break when the spark occurs, its demand upon the battery is large, so that the

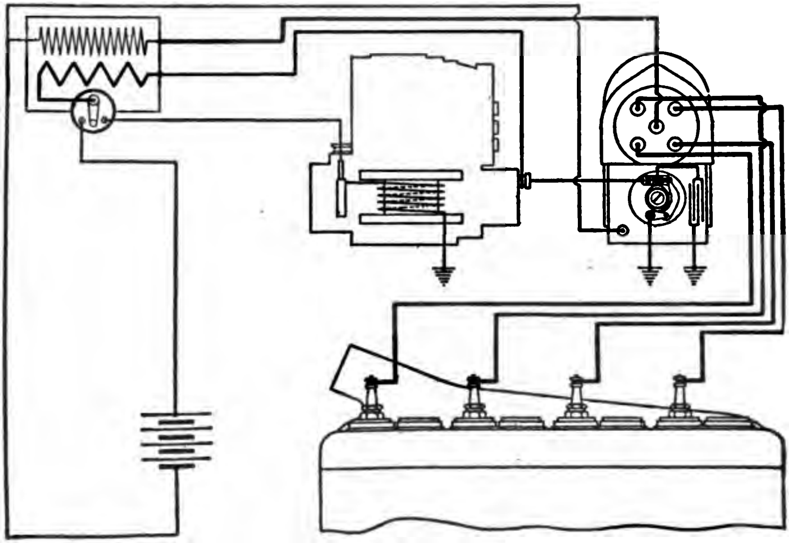

Fig. 83. Wiring Diagram of Magneto and Coil in the Remy Dual System
Courtesy of "The Horseless Age"

switch should immediately be shifted to MAGNETO as soon as the engine starts. Otherwise a dry-cell battery will be exhausted in a comparatively short time, or an unnecessary drain will be made from the storage battery where the latter is employed for starting.

Duplex Ignition System. This is designed to facilitate the starting of the motor by utilizing the current from a battery as well as that from the magneto when cranking to start. To throw the battery current in phase with that of the magneto, it having previously been stepped up to high tension through a coil on the dash, a commutator is fitted to the magneto shaft. The magneto is of the true high-tension or independent type, and by means of this commutator the flow of battery current is in the same direction as the flow of magneto current, a change in the direction of one (alternating current as generated by the magneto) is accompanied by a change in the direction of the other, and they are said to be "in phase," i.e., the cycles of alternation correspond in both. To accomplish this the battery current's polarity must be the same as that of the magneto and the battery must not be grounded, as shown by the wiring diagram, Fig. 84. The necessity for using the battery current to supplement that of the magneto exists only at very low cranking speeds, and the assistance of the battery is no longer needed once the engine starts. This type is not in general use.

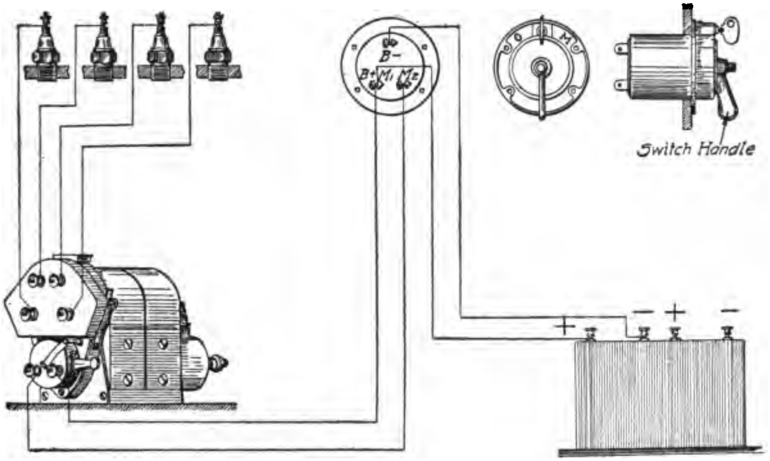

Fig. 84. Wiring Diagram of Bosch Duplex Ignition System

Double-Spark Ignition. Mention has already been made c the employment of two sparks occurring simultaneously i the cylinders under the head of "Series Plugs". It will b evident that simply by adding another distributor to a magneto and taking leads from it to a second set of plugs placed at another point in the cylinders, preferably as far away from the first as possible, the same result is accomplished. Fig. 85 shows a Remy two-spark magneto, the distributors being mounted at opposite ends of the field.

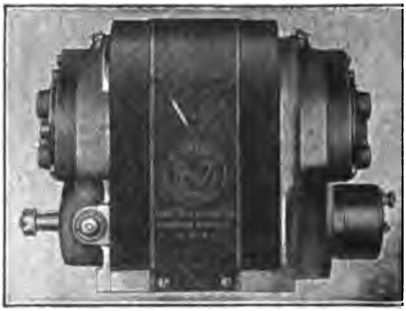

Fig. 85. Remy Two-Spark Magneto

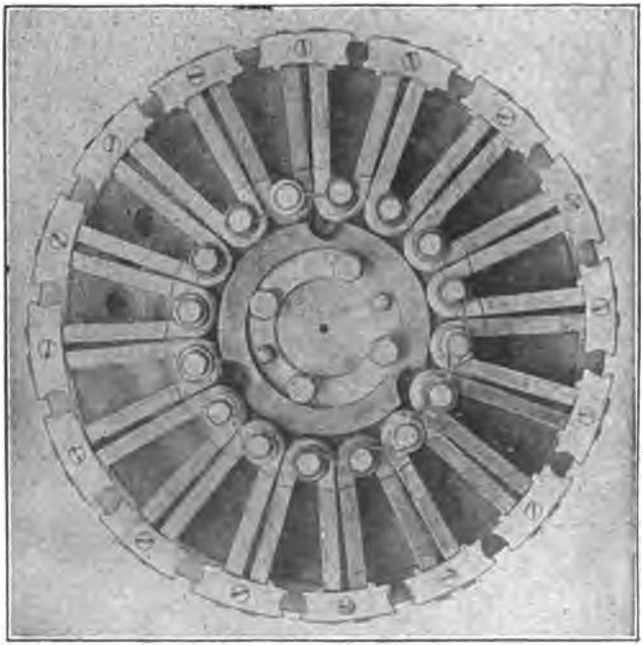

Fig. 86. Magnets of Ford Magneto

Ford Magneto. The Ford magneto is *sui generis.* What the patent lawyers term the "prior art" shows nothing even vaguely resembling it and no ignition current generator used on either

American or foreign cars, past or present, can lay claim to any family ties. Not that its principles differ in any way, but their application is very unusual, and as this magneto is now employed on more than a million cars, it is of particular interest. Instead of the two or three horseshoe permanent magnets employed on the ordinary magneto, the Ford has sixteen magnets arranged radially with their poles outward, and all are bolted directly to the flywheel, as shown in Fig. 86. Directly in front of them and separated by a very small clearance are sixteen coils, wound of copper strip or ribbon and attached to a spider which is bolted to the crankcase of the motor just forward of the flywheel, as shown by Fig. 87. The spider itself

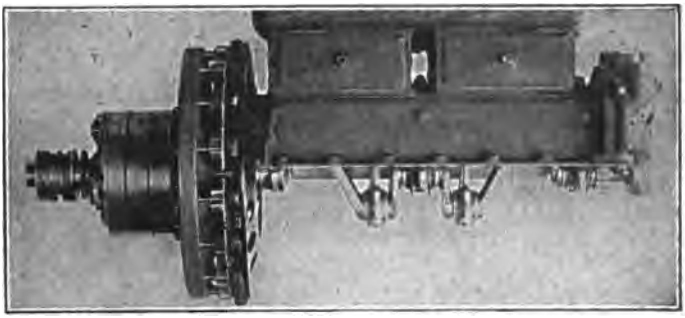
Fig. 87. Ford Magneto as Installed

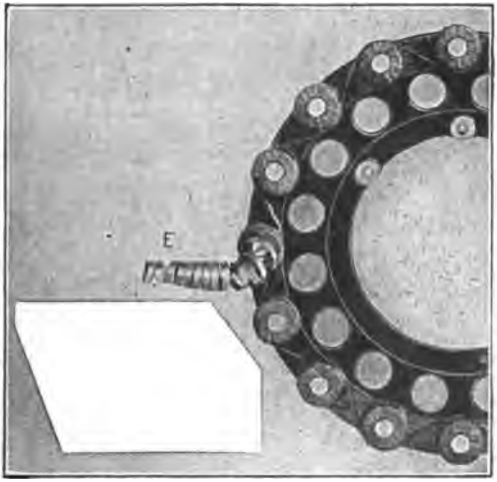

Fig. 88. Copper Ribbon Coils of Ford Magneto

and the coils are illustrated by Fig. 88, which shows one of the coils partly unwound at *E*. The spider and its coils remain stationary while the magnets are rotated in close proximity to them at high speed by the flywheel, thus inducing a current in the coil windings. The current is taken from the collector ring *B*, through the single brush *C*, the other side of the magneto circuit being grounded. Fig. 89 shows the complete ignition system as installed on the motor. The magneto is shown with part of its housing removed; at its upper center is the collecting brush mentioned, connected to the four-unit coil, which in practice is mounted on the dash. From the coil, four primary connections are made to the low-tension timer mounted at the forward end of the motor and driven from the camshaft, and the four high-tension cables for the spark plugs will be noted just below the primary connections. The other two binding posts on the back of the coil are for the current from the magneto and the ground connection. While a battery is ordinarily fitted in addition to facilitate starting, this can be accomplished on the magneto alone, as the latter is very powerful. Replacements are sold at such low prices that when the magnets have lost their strength, new ones often are inserted instead of remagnetizing the old.

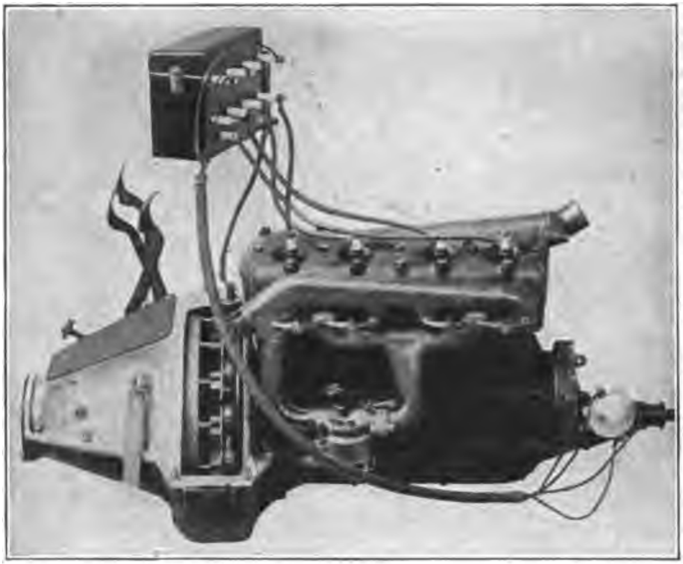

Fig. 89. Complete Ford Ignition System

Current Supply and Distribution. Except for the use of a magneto to supply the current, the system will be recognized as the ordinary coil-and-battery type now long obsolete (1909 and earlier models). Instead of the direct current provided by a battery, however, the Ford magneto supplies an alternating current which alternates sixteen times per revolution. Between each alternation, there is, of course, a momentary drop to zero so that, at the positions of the crankshaft and field magnets corresponding to this drop, there is no current in the armature, or so little that it is impossible to produce a spark. Assuming that, when the timer completes the primary circuit, the magneto is at or very near the position of zero e.m.f., the coil vibrator will not respond as the current sent through the coil by this very weak e.m.f. is not sufficient to operate it. As soon, however, as the current attains the minimum value necessary to attract the vibrator, a spark is produced. The result of this is that, as the spark timing lever is moved over its quadrant, the spark is not advanced uniformly with the lever motion. It doubtless also accounts for the fact that the motor will often be found to run much better with the lever advanced but a short part of its travel, instead of at the point of maximum advance as is the case with the ordinary magneto or with the modern battery system.

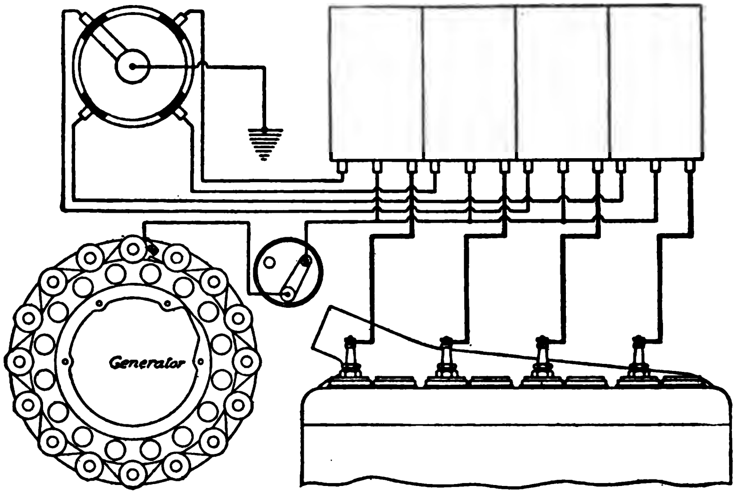

Fig. 90. **Wiring Diagram for Ford Ignition System**
Courtesy of "The Horseless Age"

Fig. 90 shows the wiring diagram of the Ford ignition system, the primary timer being indicated just above the magneto or generator. To operate efficiently, this timer needs oiling daily when the car is in constant service, and in cold weather about 25 per cent of kerosene should be added to the oil used for this purpose, as the low temperature causes the latter to thicken. To the right of the generator are shown the switch, the four vibrator coils, and the spark plugs with their leads. As the magneto has but one collector brush, it is subject to few troubles. The collector brush may loosen up through vibration and may not make proper contact, or dirt and oil may collect on the ring against which it bears, with the same result. Apart from this, the chief trouble will be caused by weakening of the magnets. A current sent through the armature coils from an outside source will tend either to strengthen or to weaken their magnetism, depending upon the direction of the current itself and the relative position of the armature with regard to the magnets. As the armature is always likely to stop in such a position that a current sent through it from an outside source will weaken the magnets, a battery should never be connected to the armature.

Misfiring. Irregular firing can be traced most frequently to the timer and will be caused either by a lack of oil or an accumulation of dirt; with the timer in good condition, misfiring will most often be due to a lack of uniformity in the adjustment of the vibrators, or to worn and pitted vibrator contacts. With the motor running, the vibrator adjustment screws should be turned up or down very slowly until all four cylinders fire uniformly. Instructions for taking care of the vibrator points are given in detail in connection with the description of battery cut-outs and circuit breakers in Part III, Starting and Lighting Systems. Failure to fire is usually due to lack of contact at the collector brush on the magneto. The timer is so located that the primary cables get the full benefit of all oil and dirt, while its movement to advance or retard the ignition is also apt to abrade the insulation from these wires close to the timer, so that irregular firing may also be due to this cause. Complete wiring replacements may be had at such low cost that when the cables become oil soaked and their insulation worn, the easiest way to correct troubles from this source is to install a new set of connections.

SPARK TIMING

Effect of Irregular Sparking. Like a steam engine, an internal combustion motor depends for its power output on the mean effective pressure developed in the cylinder, usually referred to as its m.e.p. This is affected directly by three factors: *first,* the initial compression of the charge, that is, the pressure to which the piston compresses the gaseous mixture on its upward or compression stroke just before firing; *second,* the time at which the charge is ignited; and *third,* the length of the stroke. It is with the second factor alone that this phase of the ignition problem is concerned. In contrast with the steam engine in which the steam as admitted is at a comparatively low pressure and expands gradually throughout the stroke, the pressure developed in the internal combustion motor at the moment of ignition is tremendous, but it falls off very rapidly. The impulse given the piston is more in the form of a sharp blow than a steady push, as with steam. The mean effective pressure developed depends very largely upon the pressure reached at the moment of explosion and this in turn depends upon the time ignition occurs with relation to the stroke. As the speed of an automobile motor varies over a wide range, it will be apparent that means must be employed for varying the time of explosion. To be most efficient it must occur at the point of maximum compression, i.e., when the piston is exactly at the upper dead center on the compression stroke. As both a mechanical and an electrical lag, or delay, must be compensated for, the setting which will give maximum efficiency at 500 r.p.m. will be much too slow at 1500 r.p.m. and the spark would then not take place until after the piston had started down again and the pressure had dropped considerably, causing a great loss in power. On the other hand, an attempt to run the motor slowly with a spark timing that would give the best results at high speed would often result in causing the explosion to take place against the rising piston. This is evidenced by a hammering sound and a great falling off in the power.

Advance and Retard. Means are accordingly provided in the majority of ignition systems for causing the spark to occur earlier or later in the cylinders. This is termed advancing and retarding the spark, the nomenclature being taken from the French, with whom it originated. The explanation given in the preceding paragraph for the necessity of this will make plain the car maker's often repeated injunction to the novice—never to drive *with the spark retarded.* Another and equally important reason is that when operated this way, the combustion is incomplete, the gas continues to burn throughout the stroke, and a greatly increased percentage of its heat has to be absorbed by the water jackets, causing the motor to overheat badly.

Adjusting for Time Factor of Coil. Every induction coil has a certain time constant, which represents the period necessary to completely charge the coil, that is, the time required for the current in the primary winding to attain its maximum value. This time constant depends very largely upon the amount of magnetic energy which can be stored up in the coil. There must be added to this the time required to overcome the inertia of moving parts, such as the timer and the vibrators of a high-tension battery system, or the contact breaker and the distributor in a magneto high-tension system. As these parts are very small and light this would be practically negligible for any other purpose, but when figuring in hundredths of a second, as in the case of the ignition timing of high-speed multi-cylinder motors, it becomes of importance. The object sought, as already mentioned, is to have the spark always occur at the point of maximum compression. To accomplish this with the motor running at high speed, the ignition devices must act while the piston is still an appreciable distance below upper dead center. The timer in the case of a battery system, or the contact breaker of a magneto, is accordingly mounted so that it can be turned through part of a revolution with relation to its driving shaft, or more particularly the cam carried by the latter. For starting the motor by hand, the spark must occur either at or after upper dead center is reached, never before. In the latter case, the piston would be driven backward and the familiar "back kick" result. Hence the manufacturer's admonition—always retard the spark fully before attempting to crank the motor.

Calculation of Small Time Allowance. The relation of spark advance in degrees to piston travel in inches with motors having strokes running from 3 to 8 inches is shown by the accompanying chart, Fig. 91. In this the ratio between the crank and the connecting rod length is 1 to 4.5. The lettering shown indicates the method of using the chart, the problem being to find the piston travel for an advance of 30 degrees in a motor of 6-inch stroke. The vertical line *a*, corresponding to this stroke, is traced upward until it intersects the 30-degree line at *c;* following the latter to the left brings it out at a point just below the ½-inch division, or approximately .46 inch. Assuming that the 6-inch stroke motor were running at 1800 r.p.m., its pistons would be traveling 1800 feet per minute (i.e., stroke doubled or 1 foot per revolution), 30 feet, or 360 inches per second,

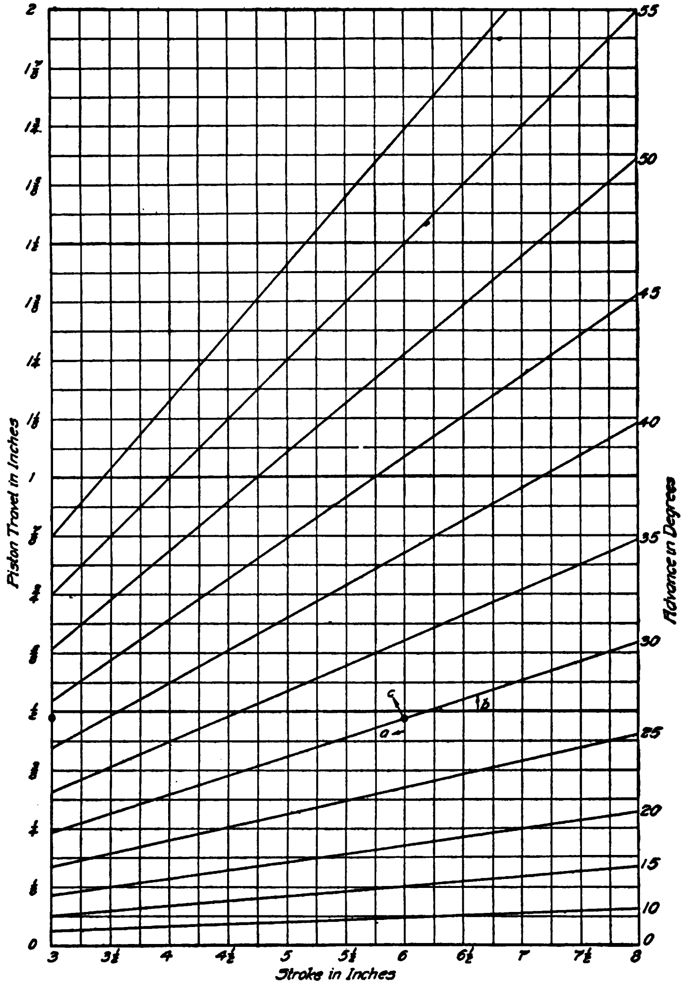

Fig. 91. Relation of Spark Advance to Piston Travel (Bosch)

so that each inch of the stroke would be covered at an average speed of 1 inch in $\frac{1}{360}$ of a second, and the $\frac{1}{2}$ inch in $\frac{1}{720}$ of a second, from which the necessity for a timing allowance will be apparent.

Magneto Timing. Timing is usually 30 to 40 degrees, which means that the spark occurrence can be advanced or retarded half that distance from a neutral line representing the upper dead center position of the piston. As shown by Fig. 92, the allowance is 34 degrees in the Splitdorf magneto, "left" and "right" in this connection having reference to the direction in which the magneto armature is driven. The necessity of providing this allowance, however, introduces a complicating factor in magneto design.

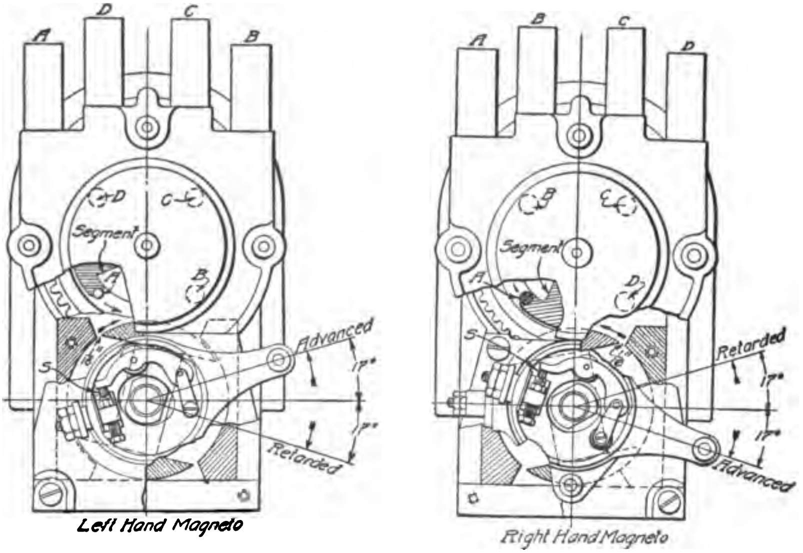

Fig. 92. Method of Advancing and Retarding Spark, Splitdorf Magneto

As the timing of the spark is accomplished by opening the contact points of the interrupter earlier or later, it will be apparent that as the magnetic field remains stationary in the ordinary magneto, the relative positions of the armature and field vary. This is illustrated by the sketch, Fig. 93, the left-hand member of which shows the position of the armature with *advanced spark*. This is the point at which the current and voltage are at their maximum, so that the most efficient spark is produced at the plugs. With the spark retarded, the armature has already had time to turn practically one, eighth of a revolution and the point of maximum intensity has been passed. While this is a factor of which much is usually made in sales literature, it is not so important as the theory of the matter would make it appear, since the spark is seldom retarded except for starting. With the modern high-speed engine there is rarely sufficient slowing down in hill-climbing to make it necessary to retard the spark, while gear-changing at the proper time further makes this unnecessary, so that practically all the time it is in service, the magneto is operating under the most efficient conditions. The great difference in the positions of the magneto armature between the advanced and the retarded points of the spark timing show why it is difficult to crank a motor by hand with the spark retarded, when relying upon the magneto for ignition.

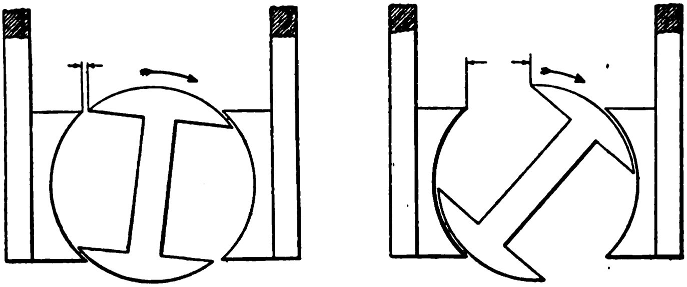

Fig. 93. Position of Magneto Armature for "Advanced" and "Retarded" Ignition

As already mentioned, most magnetos are fitted with bipolar armatures, i. e., there are two extensions, or pole pieces, between which the winding is placed. This will be clear upon reference to Fig. 94, which shows the armature core of a Simms magneto. The phases are accordingly 180 degrees apart, that is, the current in the armature winding only reaches its maximum value twice per revolution, and as these maxima are really "peaks", as shown by the oscillograph, Fig. 95, there is not much

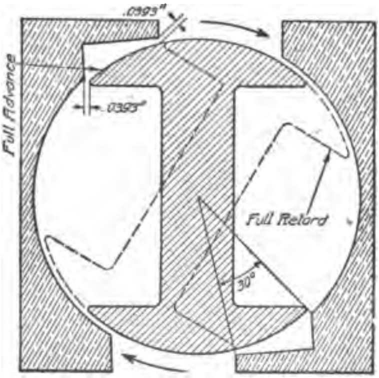

Fig. 94. Section Simms Magneto Armature and Pole Pieces

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leeway for variation one way or the other, if the greatest current value is to be utilized.

Analysis of Oscillograph Diagrams. In the oscillograph, the dotted vertical line at the left represents the moment of closing the primary circuit, the current then beginning to increase gradually in value. The resistance of this circuit is such that the current would attain a value of 5 amperes, if the circuit remained closed long enough. However, when the current has attained a value of 4 amperes, the circuit is broken by the vibrator (battery and coil system) and the current then falls off very rapidly. It will be noted that there is no current in the secondary circuit while the primary is attaining its full value, which is due to the fact that the e.m.f. induced in the secondary during this period is not sufficient to break down the resistance of the air gap in the spark plug. The spark occurs when the primary circuit is broken, and it is interesting to note that it attains its maximum value instantly, this having been confirmed by numerous oscillograph tests. The right-hand dotted line represents the moment the primary circuit is broken by the timer. With a vibrator coil a series of sparks is produced, as compared with the single spark of the magneto, but these are of no advantage except at low speeds, as when running at full speed, if the first spark fails to ignite the charge, it is already too late by the time the second occurs.

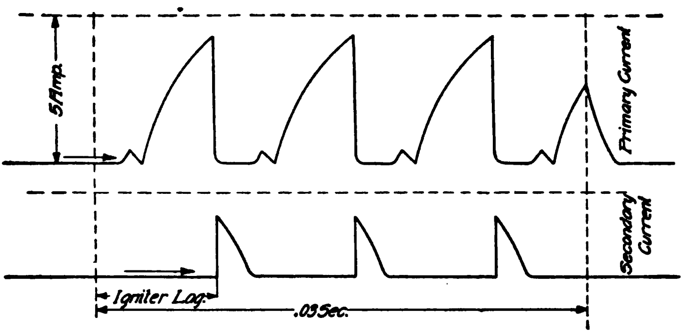


Fig. 95. Oscillograph Diagram of Primary and Secondary Currents
(*Horseless Age*)

Oscillograph diagrams taken of the current and voltage of a magneto show that both rise to a sharp peak, first in one direction and then in the reverse, as the current is alternating. As the oscillograph illustrated shows that only the peak, or maximum, value of the current in the primary of the coil can be utilized for producing a strong induced current in the secondary, so the peak of the magneto current must be taken advantage of to produce the most efficient spark. This point of maximum current value in the revolution of the armature occurs when it is cutting the greatest number of magnetic lines of force of the permanent magnetic field, which is when it is just about to pass from the influence of one set of poles into that of the other, as shown in the section, Fig. 94. This also shows the relative positions of full advance and full retard and is designed to illustrate the advantages obtained with the patent extended pole pieces of the Simms magneto, most magnetos having the upper and lower faces of both poles in the same plane.

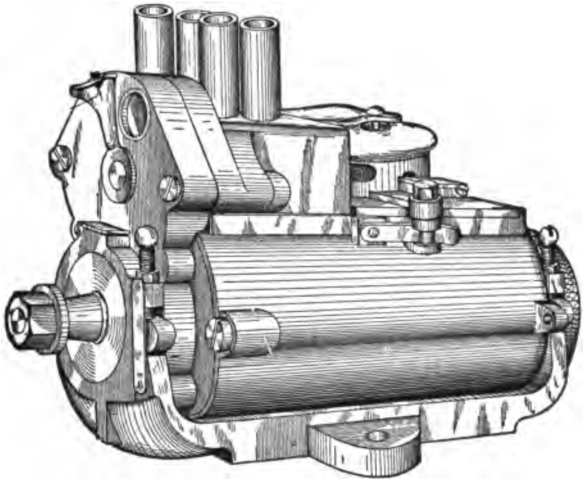


Fig. 96. Mea Magneto in Trunnion Mounting

Mea Method of Advancing Spark. Doubtless the most ingenious method of taking care of the necessity for advancing the spark has been developed in the Mea magneto, shown in Fig. 96. Instead of being of horseshoe form, as in the Bosch and Nilmelior magnetos, shown in Figs. 97 and 98, it is bell-shaped, as shown in Fig. 99. The entire magneto is carried in a trunnion mounting so that the field magnets may be turned to the same extent that the contact breaker is moved to give the necessary advance, thus insuring that the circuit will be broken with the armature in the same relative position to the field poles, which is naturally that of maximum current value.

The method of accomplishing this is shown in Fig. 100, which illustrates the relative positions of the armature and field magnets at the advanced and retarded sparking points to be the same, since the entire magnetic field is partly revolved about the armature. This movement is against the direction of rotation of the armature when advancing the spark, and with it when retarding the timing of the ignition, the illustration showing a magneto arranged to be driven *clockwise*. Fig. 101 illustrates the position of the fields when looking at the driven end of the magneto for advanced and retarded spark in both the clockwise and *anti-clockwise* types. The range of timing varies from 55 degrees to 70 degrees in the various models; and a specially long range totaling 90 degrees to 100 degrees can be provided, if necessary, by increasing the over-all height of the magneto, as the shaft must be supported higher in the trunnions to permit of this. Among the advantages of this method of ignition timing are ease of starting without a battery, quick acceleration, and a uniformly efficient spark at all positions of the sparking lever.

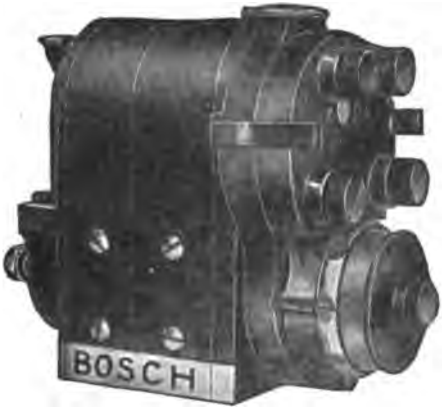


Fig. 97. Bosch Enclosed Type Magneto

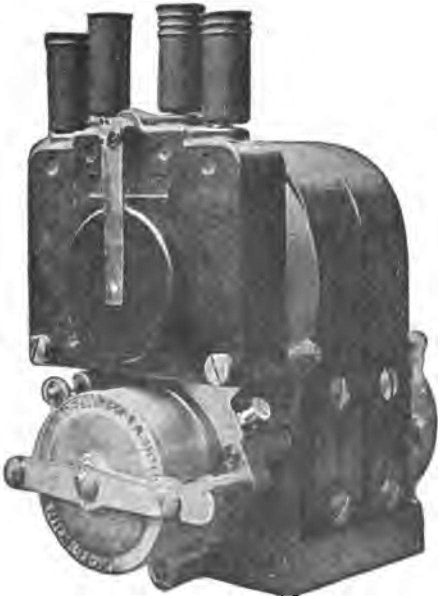


Fig. 98. Front View Nilmelior Magneto

Magneto Speeds. As the revolution of the armature of the magneto always bears a definitely fixed relation to that of the crankshaft of the engine, it will be apparent that the speed at which the magneto is driven will depend upon the number of cylinders to be fired, as well as upon the relation of the cylinders to one another, i.e., firing 180 degrees or 360 degrees a part, as measured on the crankshaft. The following are the various magneto speeds required for engines of the four-cycle type having from one to twelve cylinders:

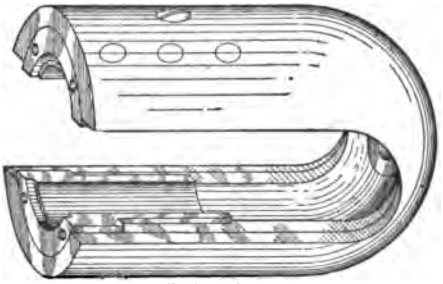


Fig. 99. Bell-Shaped Magnets of Mea Magneto

1-cylinder: Either crankshaft or camshaft speed
2-cylinder: (Impulses 360° apart, as in 2-cylinder opposed motor) camshaft speed
2-cylinder: (Impulses alternately at 180°, with 540° intervals, as in the 2-cylinder V-type motor) camshaft speed
3-cylinder: Three-fourths crankshaft speed
4-cylinder: Crankshaft speed
6-cylinder: One and one-half times crankshaft speed
8-cylinder: Twice crankshaft speed
12-cylinder: Three times crankshaft speed

Owing to the extremely high speeds necessary, the modern battery type of ignition is favored to a great extent on eight- and twelve-cylinder motors, though magnetos are built even for the latter. (See description Splitdorf 12-cylinder magneto.)

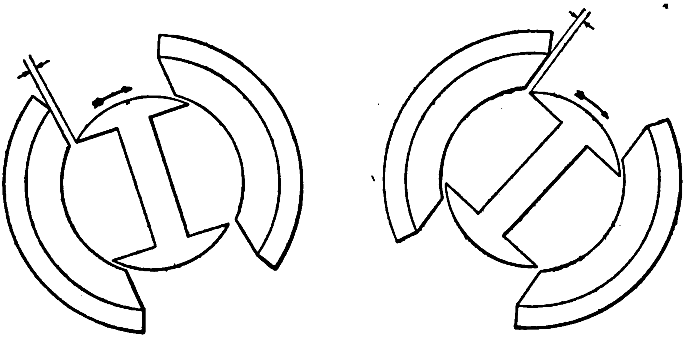


Fig. 100. Relative Position of Armature and Magnets at Moment of Sparking. in Mea Magneto

The magneto speeds necessary on two-cycle motors are twice those given above for the corresponding four-cycle types, with the exception that, on the 2-cylinder 180-degree or V-type motor, crankshaft speed would be correct.

Ignition-System Fixed Timing Point. It has become more or less general practice with French builders to provide an ignition system having a fixed timing point, i.e., one that cannot be controlled by the driver through the usual spark-advance lever as found on practically all American pleasure cars. This is particularly the case with taxicabs. While "fixed" in the sense that they are not variable while running, such systems have two firing points, one of maximum advance, which is always employed when the motor is in operation, and the other of maximum retard to enable the driver to crank the motor without danger of injury. So-called fixed-spark ignition systems have come into very general use abroad, more especially on the Continent, but have found very little favor here.

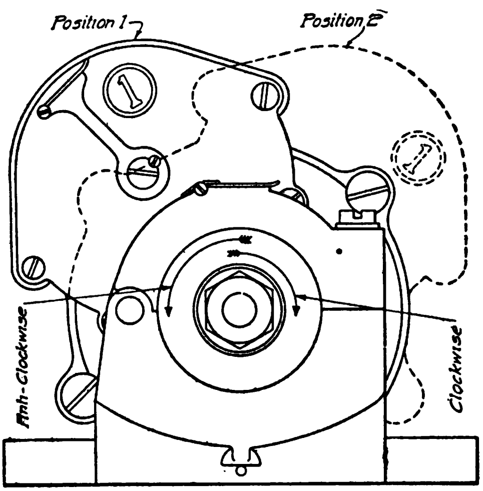


Fig. 101. Spark Advance with Meo Magneto. With Clockwise Instruments, Position 1 Supplies Advanced Spark, Position 2 Retarded Spark

Automatically Timed Systems. The stress laid by automobile manufacturers on their instructions, "always retard the spark before cranking the motor" and "always run with the spark advanced as far as possible, except when necessary to retard it owing to the motor slowing down on hills and causing a hammering noise in the cylinders", make it evident that there is a considerable amount of discretion left in the driver's hands where this important point is concerned. It is not desirable that this should be exercised by unskilled drivers, particularly those in charge of large and costly commercial vehicles, and automatically timed systems have accordingly been developed.

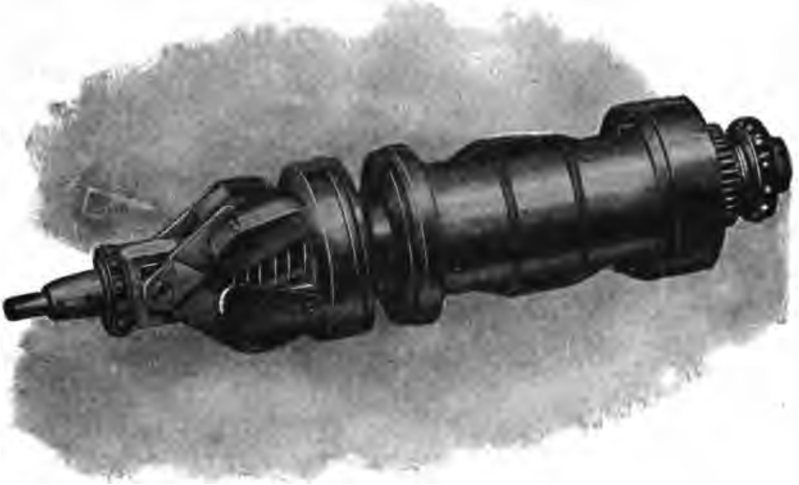


Fig. 102. Armature with Centrifugal Timing Device, Eisemann Magneto

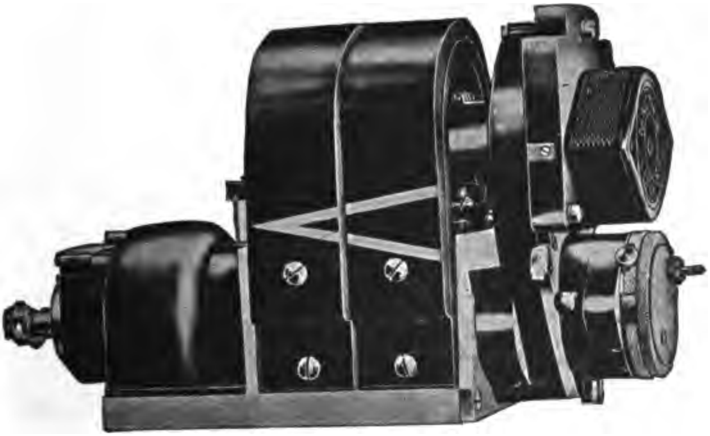


Fig. 103. Eisemann High-Tension Magneto with Automatic Timing

Eisemann Centrifugal-Governor Type. To advance the spark timing automatically, a centrifugal governor has been mounted on the armature shaft in the Eisemann magneto of this type, as shown in Fig. 102. Normally, the weights are contracted by the spring and the contact breaker is held at the fully retarded position, so that it is always safe to crank the motor without the necessity of taking any precautions. With an increase in speed, these weights tend to fly apart and in doing so they draw a sleeve and with it the armature along the shaft with them toward the left-hand end. As there are two helicoidal ridges on the shaft, however, and splines on the inner diameter of the sleeve engaging them, the sleeve is forced to make a partial revolution as it moves along the shaft, thus automatically advancing the ignition timing in accordance with the speed. The contact breaker is in fixed relation to the armature. An Eisemann magneto fitted with the automatic timing device is shown in Fig. 103. The lines drawn on the magnets indicate their polarity, so that in case the machine is taken apart it can readily be assembled again with the magnets in their proper relation.

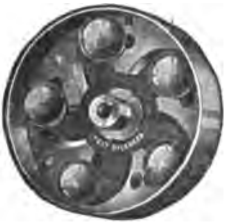


Fig. 104. Herz Automatic Spark Advance Coupling

Fig. 105. Herz Automatic Coupling (Side View)

Herz Ball-Governor Type. Another method of accomplishing the same end is the Herz automatic coupling, shown in Figs. 104 and 105. This consists of two juxtaposed disks, each of which is provided with five grooves running in a direction opposite to those of the other disk. Five steel balls are held in these grooves and act like the weights of a governor, being forced outward in direct proportion to the speed of the motor, thus imparting a twisting movement to the magneto armature with relation to its shaft. The device is supplied either as an integral part of the magneto or as an independent coupling. The range of movement is 40 degrees, the adjustment being varied by altering the curve of the grooves. Fig. 106 shows the Herz magneto. In the Eisemann, spindles having grooved slots of several different pitches are supplied, giving from 19 to 60 degrees of advance. The Atwater Kent, Connecticut, and Westinghouse ignition systems may also be had with automatic advance operated by a centrifugal governor.

Ignition Setting Point. It will be apparent that as provision is made for advancing the time of ignition beyond a certain point as well as retarding it so as to occur before that point, there must be what may be termed a neutral position. This is usually referred to as the ignition setting point. In the majority of instances, this is the upper dead center, particularly where a magneto is employed. For the reason that it is possible to start the motor by handcranking on the magneto with the time of ignition advanced very much farther than would be safe with a battery, as explained in another section, it is seldom necessary to provide for retarding the ignition timing of a magneto past upper dead center. Consequently, the ignition setting point for the majority of magnetos is upper dead center when the spark-advance lever on the quadrant is at the point of maximum retard. It is not necessary to provide for what is termed a *late* spark, i.e., one occurring after the piston has actually started down on the power stroke, nor is it necessary to provide as great a range of advance in the case of the magneto as where a battery is employed, since the magneto, to a certain extent, automatically advances the moment of ignition as the speed increases.

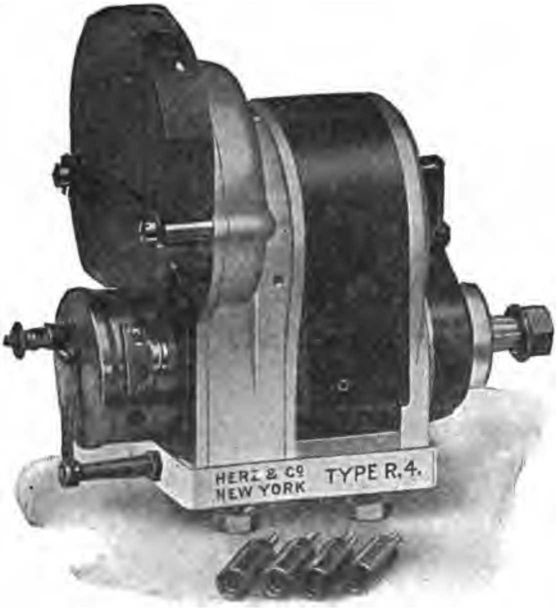


Fig. 106. Herz Magneto

Where a battery is employed, however, it is customary to allow a greater range of timing in both directions with a *late* spark to insure safety in starting, particularly by handcranking. The relation of the ignition distributor of a battery system to the crankshaft is shown in Fig. 107, which illustrates the ignition diagram of the four-cylinder Regal Motor. The firing order in this case is 1- 2- 4- 3, and it will be noted that the ignition setting point is upper dead center.

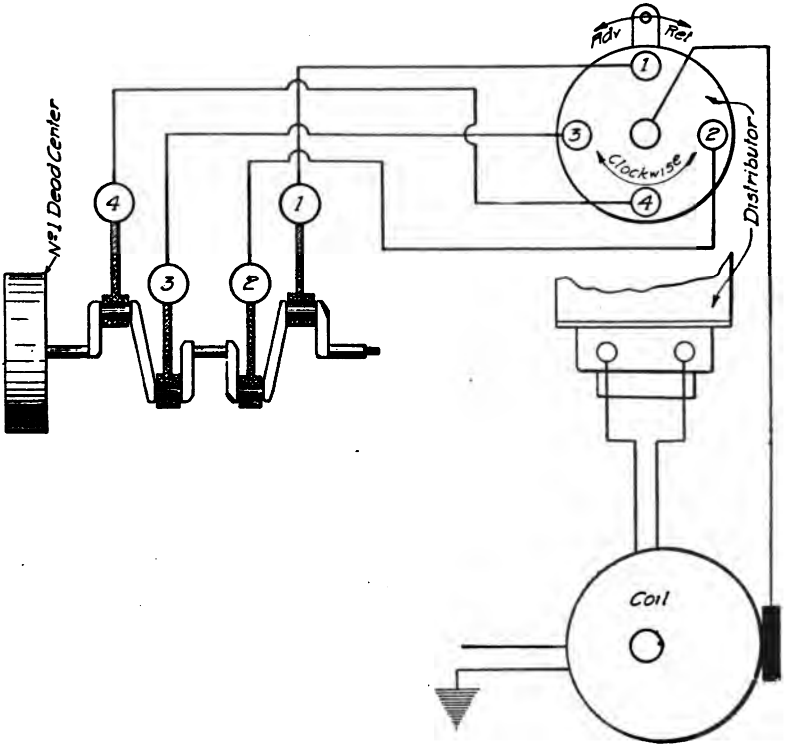


Fig. 107. Relation of Ignition Distributor to Engine Crankshaft.
Courtesy of Regal Motor Car Company, Detroit, Michigan

Both the ignition and the valve timing of practically all motors built in recent years may be checked by marks on the flywheel. A corresponding mark or pointer on the crankcase is used as a checking point.

Fig. 107 shows that when piston No. 1 is exactly at upper dead center, contact No. 1 of the distributor is under the brush leading to the spark plug of that cylinder, and, as shown by the center line, this is the ignition setting point for that motor. As the distributor turns in a clockwise direction, rotating it toward the right, as shown in the diagram, retards the time of ignition, while turning it to the left advances it. The interrupter is just below the distributor and while its battery, ground, and distributor cables are shown, the contacts themselves are not illustrated.

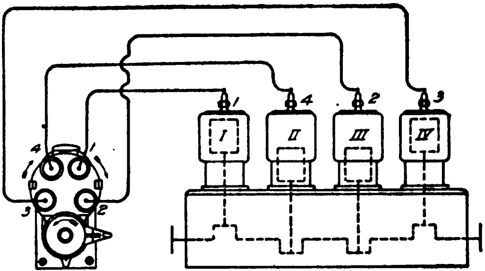
Upper Dead Center. In many cases it is no longer possible to check the ignition timing or the position of the pistons by the flywheel, as the latter is entirely enclosed. To find the upper dead center of the piston of the first cylinder it is accordingly customary to take out a spark plug and use a long knitting needle or similar piece of straight wire. While an assistant turns the motor over slowly by hand, watch the valves of cylinder No. 1. When the inlet valve of this cylinder has closed, the piston is traveling upward on the compression stroke and the needle will rise. It must be borne in mind, however, that the piston is not actually at upper dead center for ignition purposes when the needle ceases rising. In other words, a certain part of the revolution of the crank is not represented by a corresponding movement of the piston, and the proportion that this bears to the whole revolution naturally increases with the length of the stroke.

The starting crank should accordingly be turned until the needle actually starts downward again on the firing stroke, and then the motor turned backward again slightly until it ceases to rise. This may be done by putting the gear lever in *high,* engaging the clutch, jacking up one rear wheel and turning it backward. This will give the proper ignition setting point for any system in which this point is given as "upper dead center with the spark at the point of maximum retard". But unless the precaution in question is taken, the spark timing will have a slight amount of advance and, in a long-stroke motor using a battery system of ignition, this may be sufficient to cause the motor to kick back when cranked slowly by hand.

In some cases, where the flywheel rim is not accessible, the ignition setting point is marked on the distributor itself.

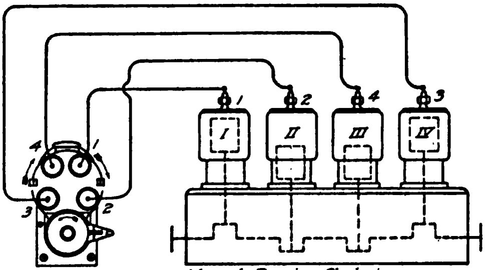
FIRING ORDER

Typical Firing Orders. It is naturally quite as important that the sparks occur in the different cylinders of a multi-cylinder motor in the proper order as that each individual spark should take place



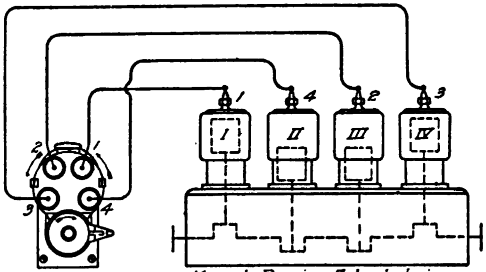
View of Distributor End

Magneto Running Clockwise Firing Sequence I, III, IV, II.



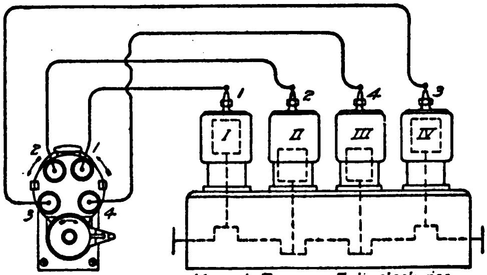
View of Distributor End

Magneto Running Clockwise Firing Sequence I, II, IV, III.



View of Distributor End

Magneto Running Anti-clockwise Firing Sequence I, III, IV, II.



View of Distributor End

Magneto Running Anti-clockwise Firing Sequence I, II, IV, III

Fig. 108. Firing Order of Four-Cylinder Motors (*Bosch Magneto Company*)

at just the right moment. Regardless of the number of cylinders, the crankshaft throws are always in pairs. Hence, the pistons rise and fall in pairs, and the cylinders of these pairs (which have no relation whatever to the method of casting the cylinders themselves) naturally cannot follow each other in firing, the firing order alternating from one pair to the other. For example, 1- 3- 4- 2- as in the upper diagram of Fig. 108, or 1- 2- 4- 3- as in the diagram just below it, the motors in both these instances running "clockwise", i.e., with the crankshaft turning from left to right. A similar variation is possible with the motor turning "anti-clockwise", or from right to left, as shown in the two lower diagrams, which show firing orders of 1- 3- 4- 2- and 1- 2- 4- 3- the changes being made by shifting the distributor connections to the spark plugs of the various cylinders. In the case of a high-tension battery system using unit coils, the timer connections are varied in the same manner. In six-cylinder motors the crank throws are 120 degrees apart, but as the pistons are attached in pairs to cranks in the same plane, the method of distributing the firing order among them is similar to that already given. The Bosch dual ignition system, as installed on the six-cylinder Winton, is a typical firing order for a six. As shown by Fig. 109, this runs 1- 5- 3- 6- 2- 4.

Possible Combinations. There are so many possible firing orders in the six-cylinder motor and likewise in the more recent eight-cylinder and twelve-cylinder motors that one of the most puzzling questions arising in the repair shop frequently has been to determine just which one has been adopted by the manufacturer for his particular motor. So much uncertainty exists that many makers have solved this for the repair man by attaching a plate to the motor or to the dash, giving the firing order. There are eight firing orders possible for the six or eight. With the six these are:

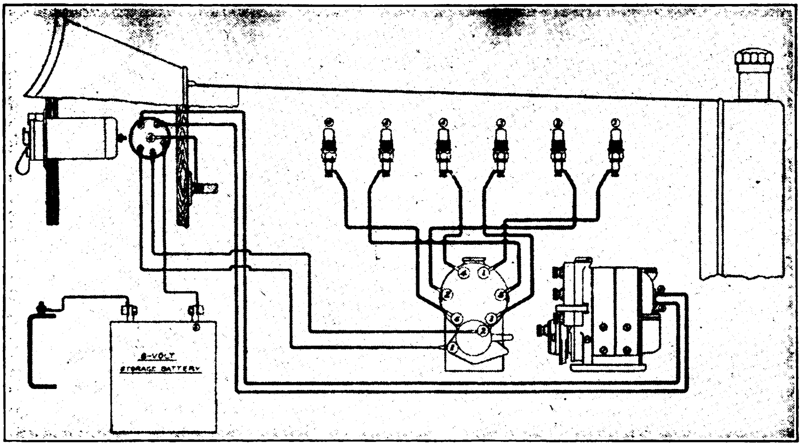


Fig. 109. Firing Order of Six-Cylinder Winton Motor

(a) 1 2 3 6 5 4
(b) 1 2 4 6 5 3
(c) 1 3 2 6 4 5
(d) 1 3 5 6 4 2
(e) 1 4 5 6 3 2
(f) 1 5 4 6 2 3
(g) 1 4 2 6 3 5
(h) 1 5 3 6 2 4

While any of these firing orders will give an equally good impulse balance, the question of proper distribution of the incoming charge and the free escape of the exhaust also have an important bearing on the matter, so that the last two orders given are in most general use. The Winton Six, Fig. 109, shows the employment of order (h).

For the V-type eight-cylinder motor, the possible firing orders are as follows:

(i) 1R 1L 2R 2L 4R 4L 3R 3L
(j) 1R 1L 3R 3L 4R 4L 2R 2L
(k) 1R 4L 2R 3L 4R 1L 3R 2L
(l) 1R 4L 3R 2L 4R 1L 2R 3L
(m) 1R 1L 3R 2L 4R 4L 2R 3L
(n) 1R 1L 2R 3L 4R 4L 3R 2L
(o) 1R 4L 2R 3L 4R 1L 3R 3L
(p) 1R 4L 2R 3L 4R 1L 2R 2L

As the last four mentioned involve different firing orders in each set of four cylinders, they need not be considered. With the rocker-arm type of valve lifters using only eight cams, as in the De Dion (French, and the first to use an eight-cylinder motor), Cadillac, and King engines, it is only possible to use the orders k and l, while, as a matter of fact, all three employ the order given in l, which is shown diagrammatically in Fig. 110. The other possible order for an eight (k) may be read from the same diagram by turning it around and changing the numbers from 4L to 1R, 3L to 2R,

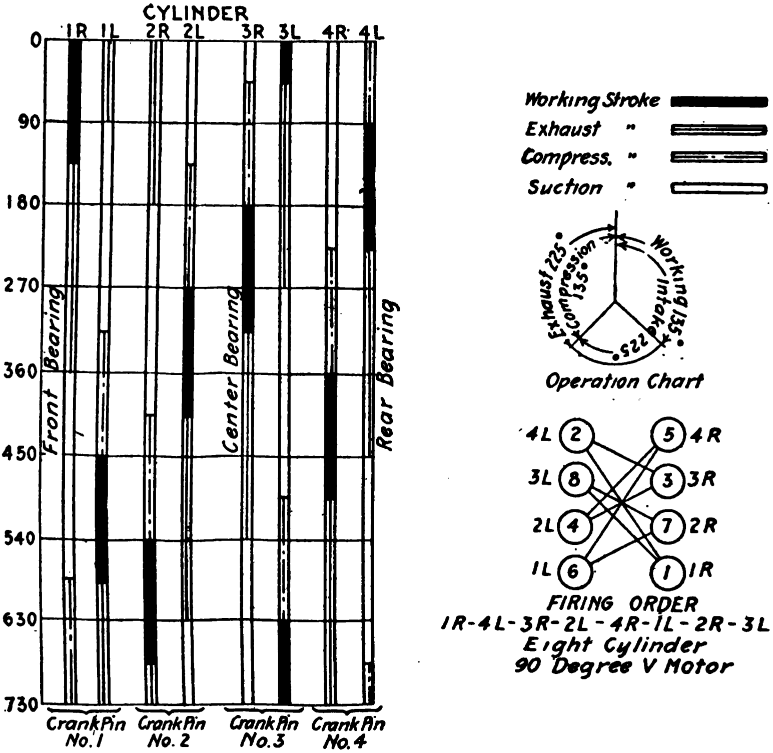


Fig. 110. Firing Order of Eight-Cylinder, V-Type Motor
Courtesy of "Automobile Topics", New York City

and so on. A curious fact is that in each of these orders the sum of the numbers of two cylinders which fire in succession is always 5. By starting always with a right-hand cylinder, the firing order can readily be determined by noting whether the firing order in one of the groups of four cylinders is 1- 3- 4- 2 or 1- 2- 4- 3.

Just as the eight-cylinder V-type motor is simply a combination of two groups of four cylinders, each of which considered alone would have the standard firing order of a four, so the twelve-cylinder V-motor is simply the bringing together on one crankshaft of two six-cylinder motors. The firing order adopted is accordingly one of the two preferred for the six-cylinder motor (**g** and **h**), alternating from the right-hand to the left-hand group in the same manner as shown for the eight-cylinder motor.

Firing Orders and Ignition Advance. Repairs and adjustments to the ignition system of a motor are always much easier to carry out when the characteristics of the system in question are known. For this reason the firing orders of the various models of different makes, together with the setting point and the amount of advance and retard, are given here for practically all makes of cars. Whereever it could be obtained, this information is given for all models of every make for the past five years, but in some instances it was not available. The information is given in the alphabetical order of the makers' names to make reference easy.

Allen

1917 Fours. Firing order 1- 2- 4- 3.

Battery ignition; extreme retard, dead center; maximum advance 30°.

Apperson

1914–15 Fours. F.O. 1- 3- 4- 2.

1915–16–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1916–17 Eights. F.O. 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L.

Extreme retard, dead center; maximum advance 15°.

Auburn

Sixes. Models Six-45, Six-46, and Six-47.

F.O. 1- 4- 2- 6- 3- 5.

Models Six-40, Six-40A, Six-44, Six-38, and Six-39.

F.O. 1- 5- 3- 6- 2- 4.

Most of the above models are equipped with battery ignition.

Austin

Twelves. F.O. 1R- 1L- 4R- 4L- 3R- 3L- 6R- 6L- 2R- 2L- 5R- 5L.
Delco system.

Biddle

Fours. F.O. 1- 3- 4- 2.
Magneto setting; full retard, upper dead center.

Bour-Davis

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Brewster

Fours. F.O. 1- 3- 4- 2.
Magneto setting; maximum advance when piston is 5 mm. (practically ⅕ inch) below upper dead center.

Briscoe

Fours. F.O. 1- 3- 4- 2.
Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.
Ignition setting; upper dead center; maximum advance 15°.

Buick

1913 Fours. F.O. 1- 3- 4- 2.
Remy Model, RL magneto; extreme retard, dead center; maximum advance about 30°.
1914–16 Fours. F.O. 1- 3- 4- 2.
Sixes. F.O. 1- 4- 2- 6- 3- 5.
All models since 1913 Delco battery-ignition system; extreme retard, 7° beyond dead center, except on Models B-24-5 and 36-7, on which retard is 40°; maximum hand advance 50° to 72°. Models D-44-5, D-54-55, C-54-55, 15° automatic advance. Models C-36-37 and C-4, automatic advance 24° 32′.

Cadillac

Fours. F.O. 1- 2- 4- 3.
Sixes. F.O. 1- 7- 3- 5- 4- 2- 6- 8.

Case

1914–15–16–17 Fours. F.O. 1- 3- 4- 2.
Extreme retard, dead center; maximum advance 30°.

Chadwick

Sixes. F.O. 1- 3- 2- 6- 4- 5.

Chalmers

1912–13–14 Fours. F.O. 1- 3- 4- 2.
Magneto setting; extreme retard, dead center.

1914 Sixes. F.O. 1- 4- 2- 6- 3- 5.
Magneto setting; extreme retard, dead center; advance 1½ inches on flywheel.
1915 Sixes. F.O. 1- 4- 2- 6- 3- 5.
Atwater Kent battery system; extreme retard, 1½ inches on flywheel.
1915 Sixes. F.O. 1- 4- 2- 6- 3- 5.
Magneto setting; extreme retard, dead center.
1916 Sixes. F.O. 1- 4- 2- 6- 3- 5.
Atwater Kent battery system; extreme retard, dead center.
1916 Sixes. Model 35. F.O. 1- 4- 2- 6- 3- 5.
Remy magneto setting; extreme retard, dead center.

Chandler

All Models. F.O. 1- 5- 3- 6- 2- 4.
Magneto; extreme retard; interrupter opens at top dead center; this is when back edge of magneto armature is central between pole pieces; maximum advance 30° to 35° at the magneto or 20° to 25° at the crankshaft.

Chevrolet

1912–17 Fours. F.O. 1- 2- 4- 3.
Sixes. F.O. 1- 4- 2- 6- 3- 5.
Eights. F.O. 1L- 3R- 2L- 1R- 4L- 2R- 3L- 4R.

Chicago

Sixes. F.O. 1- 5- 3- 6- 2- 4.
Battery ignition setting; extreme retard, upper dead center.

Coey

Fours. F.O. 1- 3- 4- 2.
Sixes. F.O. 1- 4- 2- 6- 3- 5.

Cole

1912–14–15 Sixes. F.O. 1- 5- 3- 6- 2- 4.
1912–13 Fours. F.O. 1- 3- 4- 2.
1916–17 Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.
Battery ignition on all later models.

De Dion

Fours. F.O. 1- 3- 4- 2.
Eights. 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L.
Magneto fixed ignition; setting point, 6 to 10 mm. before upper dead center.

Dixie

Four. F.O. 1- 3- 4- 2.

Dodge

All Models. F.O. 1- 3- 4- 2.

Eisemann magneto; setting point at extreme retard, 5° in advance top dead center; maximum advance 30°.

Dorris

Fours. F.O. 1- 3- 4- 2.

Magneto set to fire at upper dead center when fully retarded.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Same setting; maximum advance 35°.

Dort

All Models. F.O. 1- 3- 4- 2.

Battery ignition system.

Elkhart

Fours. F.O. 1- 3- 4- 2.

Empire

Model 31. F.O. 1- 2- 4- 3.

On motors with chain-driven camshaft. Magneto; fixed ignition point 17° in advance of dead center.

Model 31. F.O. 2- 1- 3- 4.

On motors having a gear-driven camshaft.

Models 33 and 31–40. F.O. 1- 2- 4- 3.

Battery ignition with Remy distributor; extreme retard, upper dead center.

Models 40, 45, and 50. F.O. 2- 1- 3- 4.

Battery ignition.

Models 60 and 70. F.O. 1- 5- 3- 6- 2- 4.

Battery ignition; extreme retard, upper dead center.

Enger

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Twelves. F.O. 1R- 1L- 5R- 5L- 3R- 3L- 6R- 6L- 2R- 2L- 4R- 2L.

Battery ignition. It will be noted that this is exactly the same as the firing order of the sixes, except that the order alternates from one group to the other; this is true of most eight-cylinder and twelve-cylinder motors; that is, the firing order is equivalent to that of two alternate fours or sixes.

Erie

Fours. F.O. 1- 2- 4- 3.

Fiat

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Ford

Fours. All Fours since 1906. F.O. 1- 2- 4- 3.

Sixes. Built about 1905 or 1906. F.O. 1- 2- 3- 6- 5- 4.

The Ford magneto is not timed to the engine; owing to the large number of poles and armature coils, it delivers a constant current (alternating) which is timed by the commutator, or timer, in the same manner as with a battery source of supply.

Franklin

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting point measured on rim of flywheel, 1½ inches for Franklin series 5, 6, 7, and 8 motors; 2½ inches for series 9 motor. In the series 5–8, inclusive, the flywheel is 18 inches in diameter, while in series 9 it is 17 inches. Maximum advance series 5–8, 7½ inches on flywheel; series 9, 7 inches.

F. R. P.

Fours. F.O. 1- 2- 4- 3.

Contact points of magneto open when magneto armature is ⅝ inch from pole piece, piston being at upper dead center. This gives spark at approximately dead center, with full retard. Advance is maximum afforded by magneto used.

Glide

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting; extreme retard, upper dead center.

Grant

Fours. F.O. 1- 2- 4- 3.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Hollier

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Eights. F.O. 1- 6- 3- 5- 4- 7- 2- 8.

Battery ignition, Remy system on the six-cylinder model and Atwater Kent on the eight-cylinder. Ignition setting; extreme retard, upper dead center; maximum advance approximately 15°.

Homer-Laughlin

1916 Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.
1917 Eights. F.O. 1- 6- 3- 5- 4- 7- 2- 8.

Magneto setting point approximately 5° after piston passes upper dead center; maximum advance about 30°.

Hudson

Sixes. F.O. 1- 5- 3- 6- 2- 4.

The following instructions for ignition setting as applied to the Delco ignition system used on the Hudson cars are also applicable, with slight modifications, to practically all cars using this system, although the amount of advance will naturally differ in many cases. First, remove the distributor head and measure the gap between the distributor contacts. This should be done when they are opened to the maximum. The gap should be set at .012 to .018 inch, using the feeler gage on the Delco distributor wrench provided for this purpose. Set the spark lever at the top of the quadrant or in the fully advanced position; open all the priming cocks. When No. 1 cylinder blows air out of its priming cock, its piston is rising on the compression stroke.

On Model Six-40, 1914, No. 1 cylinder is due to fire in the advanced position when the line *A* on the flywheel reaches the pointer attached to the crankcase. This may be observed through the inspection hole on the flywheel housing on the left side of the motor. This line *A* is 2¾ inches before dead center for cylinders Nos. 1 and 6. The 1915–16 Six-40 Models are due to fire on No. 1 cylinder ½ inch before dead center; 1914–16 Model 54, 6 inches before dead center; 1916 Super Six, ⅝ inch before dead center, the setting in each case being checked by bringing the line *A* on the flywheel directly opposite the pointer.

After the piston of No. 1 cylinder has been brought to the proper position, loosen the cam on the distributor shaft by turning out the set screw in the center of the shaft. Set the distributor so that when the contacts are just opening, the button on the rotor comes under No. 1 on the distributor head. The spark occurs the instant the contacts separate. In checking the timing, the cam should be held in tension against its direction of rotation, which is *clockwise*, so that all play, or *blacklash*, will be taken up. The set screw must always be screwed home tight after checking or making an adjustment, to prevent its slipping. The rotor should now be replaced on the distributor shaft, first rubbing a slight amount of vaseline on the rotor track with the finger, and the distributor head put back in position tightly.

Hupp

Up to 1912. Model 20. F.O. 1- 2- 4- 3.
Bosch high-tension magneto; fixed firing point.
Up to 1915. Model 32. F.O. 1- 2- 4- 3.
Magneto; manual advance.
Models K and N. F.O. 1- 2- 4- 3.
Atwater Kent; manual and automatic spark advance.
1911–12. F.O. 1- 3- 4- 2.
Magneto; extreme retard, upper dead center; advance 37½°.

Interstate

1915–17. Model T. F.O. 1- 2- 4- 3.
Magneto setting; extreme retard, upper dead center; maximum advance 20°.
1914–15. Model 45. F.O. 1- 5- 3- 6- 2- 4.
Extreme retard, upper dead center; maximum advance 37½°.

Jackson

1917. Model 349. F.O. R1- L1- R3- L3- R4- L4- R2- L2.

Jeffery

1913 Fours. F.O. 1- 2- 4- 3.
1914 Fours. F.O. 1- 3- 4- 2.
Advance 35°.
1915 Fours. F.O. 1- 3- 4- 2.
Advance 35°.
1915 Sixes. Model 104. F.O. 1- 5- 3- 6- 4- 2.
Advance 22½°.
Sixes. Model 106. F.O. 1- 4- 2- 6- 3- 5.
Advance 22½°.
1916 Sixes. Model 96. F.O. 1- 4- 2- 6- 3- 5.
Advance 22½°.
Sixes. Model 661. F.O. 1- 5- 3- 6- 2- 4.
Advance 24°.

Fours. Models 462 and 472. F.O. 1- 3- 4- 2.
Advance 28°.
1917 Sixes. F.O. 1- 5- 3- 6- 4- 2.
Advance 28°.
Fours. F.O. 1- 3- 4- 2.
Advance 28°. Magneto setting point all models; spark lever full retard, dead center.

King

1913–14 Fours. F.O. 1- 3- 4- 2.
1915–16 Eights. F.O. 1L- 8R- 3L- 6R- 4L- 5R- 2L- 7R.
Battery ignition; automatic spark advance; extreme retard, upper dead center; advance increases automatically with speed of motor.

Kisselkar

Fours. F.O. 1- 3- 4- 2.
Sixes. Models F11, G9, and G10, 1912–15, Six-60 and Six-48. F.O. 1- 4- 2- 6- 3- 5.
Model Six-42 and Hundred Point Six. F.O. 1- 5- 3- 6- 2- 4.

Kline

Fours. F.O. 1- 2- 4- 3.
Up to and including 1914 Sixes. F.O. 1- 4- 2- 6- 3- 5.
1915–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Lexington-Howard

1908–12 Fours. F.O. 1- 3- 4- 2.
1914–15 Fours. F.O. 1- 3- 4- 2.
1913–14 Sixes. F.O. 1- 5- 3- 6- 2- 4.
1915–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.
Setting point with full retard, dead center.

Liberty

Sixes. F.O. 1- 5- 3- 6- 2- 4.
Distributor set 1 inch late.

Locomobile

1910–12 Fours. F.O. 1- 2- 4- 3.
1913 Sixes. F.O. 1- 5- 3- 6- 2- 4.
The armature shaft of the magneto is set so that the H-shaped core is 14 millimeters, or .551 inch, from the pole piece of the magneto for Model 30 and 21 millimeters, or .827 inch, for Models 38 and 48.

1914–15 Sixes. F.O. 1- 5- 3- 6- 2- 4.

The armature shaft of the magneto is set so that the H-shaped core is 21 millimeters, or .827 inch, from the pole piece of the magneto in Model 38 and 25 millimeters, or .985 inch, for Model 48.

1916–17. F.O. 1- 5- 3- 6- 2- 4.

The magneto is set so that with the spark lever fully advanced, the spark occurs while the piston is still $\frac{7}{16}$ inch from upper dead center on Model 48 and $\frac{5}{16}$ inch on Model 38.

McFarlan

1912 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Eisemann magneto; interrupter set back of center at full retard, $\frac{1}{2}$ inch.

1913 Sixes. Teetor motor. F.O. 1- 5- 3- 6- 2- 4.

Interrupter set back of center at full retard, $\frac{1}{2}$ inch.

Herschel motor. F.O. 1- 4- 2- 6- 3- 5.

Eisemann magneto; interrupter set back of center at full retard, $\frac{1}{2}$ inch.

1914 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Mea magneto; interrupter set back of center at full retard, $\frac{1}{2}$ inch.

1915–17 Sixes. F.O. 1- 5- 3- 6- 4- 2.

Westinghouse and Bosch; interrupter set back of center at full retard, $\frac{3}{4}$ inch. The amount of advance provided is 25° on the interrupter housing, with the exception of Model 65, which has $15\frac{1}{2}$° automatic advance and $17\frac{1}{2}$° hand advance.

Madison

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Battery ignition.

Marion-Handley

1916–17 Sixes. F.O. 1- 5- 3- 6- 4- 2.

Marmon

Up to 1912 Fours. F.O. 1- 3- 4- 2.

1913–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting point, with spark lever fully retarded, one inch past upper dead center, as measured on flywheel; maximum advance 35°.

Maxwell

Model 25. F.O. 3- 4- 2- 1.

Magneto is set to fire, with spark lever at fully retard when piston has traveled $\frac{1}{32}$ inch down on firing stroke.

Mercer

1913–17 Fours. F.O. 1- 3- 4- 2.

Magneto setting, with spark lever fully advanced, 1 inch before piston reaches upper dead center, or 41° on flywheel.

Militaire

Fours. F.O. 1- 3- 4- 2.

Setting point; extreme retard, upper dead center.

Mitchell

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

1912–14 Models, inclusive.

Magneto setting; extreme retard, upper dead center.

1915–16 Models, inclusive.

Battery ignition; setting point, 10° past upper dead center; maximum advance 40°.

Moline

All Models. Fours. F.O. 1- 3- 4- 2.

Magneto, set to fire at upper dead center with spark lever fully retarded.

Monroe

Fours. Model 2. F.O. 1- 2- 4- 3.

Models, 3–4. F.O. 1- 3- 4- 2.

Battery ignition.

Moon

1916–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Murray

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Magneto setting; extreme retard, 1 inch past center line on flywheel.

National

1913–16 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1916–17 Twelves. F.O. 1- 12- 9- 4- 5- 8- 11- 2- 3- 10- 7- 6.

Magneto setting point, with spark lever fully advanced, 1¼ inches on flywheel before piston reaches upper dead center.

Google

Oakland

All Four-Cylinder Models. F.O. 1- 3- 4- 2.

All Sixes. F.O. 1- 5- 3- 6- 2- 4.

Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.

Maximum advance allowed, 24°.

Oldsmobile

Models 42–43. Fours. F.O. 1- 3- 4- 2.

Delco battery ignition system; maximum advance 80°; maximum retard 40°, measured on flywheel, on all models.

Model 54. Sixes. F.O. 1- 5- 3- 6- 2- 4.

Model 44. Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.

Packard

Up to 1912. Fours. F.O. 1- 2- 4- 3.

Magneto setting point, with spark lever fully advanced, $\frac{15}{16}$ inch before piston reaches upper dead center.

1912–15 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting point, with spark lever fully advanced, $\frac{7}{16}$ to $\frac{1}{2}$ inch before piston reaches upper dead center.

1916–17 Twelves. F.O. 1R- 6L- 4R- 3L- 2R- 5L- 6R- 1L- 3R- 4L- 5R- 2L.

It will be noted that this firing order is the same in each block of six cylinders, beginning with No. 1 in the right block and following with No. 6 in the left, as in the six-cylinder model.

Maximum advance, $\frac{7}{8}$ inch before piston at upper dead center.

The variation in the amount of advance allowed is accounted for by the difference in speed. The four-cylinder motors were equipped with a low-tension magneto having a considerable ignition lag, so that a large amount of advance was necessary. The six-cylinder motors ran at a higher speed and were equipped with a high-tension magneto in which the ignition lag was greatly reduced, so that not as much advance was necessary. While the ignition system of the twin-six motor has no greater lag than the high-tension magneto used on the six-cylinder motor, the speed is so much greater that an amount of advance approximately equal to that of the much slower four-cylinder motor is necessary.

Paige-Detroit

1911–14 Fours. F.O. 1- 3- 4- 2.

1915–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Pathfinder

Twelves. F.O. 1R- 1L- 4R- 4L- 2R- 2L- 6R- 6L- 3R- 3L- 5R- 5L.

Battery ignition.

Patterson

1911–12–13 Fours. Models 30, 41, 43, 45, and 47. F.O. 1-3-4-2.

1914–15. Model Four-32. F.O. 1- 3- 4- 2.

1915 Sixes. Model Six-48. F.O. 1- 5- 3- 6- 2- 4.

1916. Model Six-42. F.O. 1- 5- 3- 6- 2- 4.

1917. Model Six-45. F.O. 1- 5- 3- 6- 2- 4.

Magneto settings; extreme retard, dead center, on all models.

Peerless

1912 Fours. F.O. 1- 2- 4- 3.

Sixes. Models J and K. F.O. 1- 3- 2- 6- 4- 5.

Sixes. Model L. F.O. 1- 4- 2- 6- 3- 5.

1913–14 Sixes. F.O. 1- 4- 2- 6- 3- 5.

1915 Sixes. Model 5K. F.O. 1- 4- 2- 6- 3- 5.

Sixes. Model EE. F.O. 1- 5- 3- 6- 2- 4.

Fours. Model DD. F.O. 1- 3- 4- 2.

1916 Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

1917 Eights. F.O. 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L.

Model 2J. Full advance is equivalent to $3\frac{1}{2}$ inches before dead center, as measured on the flywheel.

Model 2K, $3\frac{5}{8}$ inches before dead center.

Model 2L, $2\frac{7}{8}$ inches before dead center.

Model 5K, 4 inches before dead center.

Model TC (commercial motor), 28°, or 4.68 inches, before dead center on maximum advance and 7°, or 1.17 inches, past dead center on full retard.

Last 50 Model 2K, $2\frac{3}{4}$ inches full advance instead of $3\frac{5}{8}$ inches.

Pierce-Arrow

All Sixes. F.O. 1- 5- 3- 6- 2- 4.

Model C4. Magneto set to have interrupter contacts open when magneto mark on flywheel is directly opposite pointer on crankcase; battery system; spark occurs when igniter mark on flywheel is opposite pointer on crankcase and mark indicating cranks of Nos. 1 and 6 cylinders is directly on top center.

Model B4. Magneto set to have interrupter contacts open when magneto mark on flywheel registers with pointer and mark indicating cranks of Nos. 1 and 6 cylinders is $\frac{3}{16}$ inch over top center; battery system; spark occurs when igniter mark on flywheel registers with pointer and mark indicating cranks Nos. 1 and 6 cylinders is directly on top center.

Model A4. Magneto set to have interrupter contacts open when magneto mark on flywheel registers with pointer and mark indicating cranks Nos. 1 and 6 cylinders is $1\frac{3}{4}$ inches over top center; battery system; spark occurs when igniter mark on flywheel registers with pointer and mark indicating cranks Nos. 1 and 6 cylinders is $\frac{1}{4}$ inch over top center.

Pilliod

Fours. F.O. 1- 3- 4- 2.

Magneto set to give 15° retard and 15° advance.

Premier

1916–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

With the spark lever fully retarded, the breaker points are set to open 2° to 3° late on flywheel, while the maximum advance is 25°. The pistons are not accessible when motor is fully assembled.

Princess

Fours. F.O. 1- 2- 4- 3.

Setting point for magneto, 8° past dead center at full retard; maximum advance 20°.

Pullman

Fours. F.O. 1- 2- 4- 3.

Regal

All Fours except 1915–16. F.O. 1- 2- 4- 3.

1915–16 Fours. F.O. 1- 3- 4- 2.

1916–17 Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

The magneto in earlier models and battery-ignition system in later cars set to fire at upper dead center, with spark lever in fully retarded position. Remy magneto on 1909–10 cars; Michigan magneto 1910–14; Atwater Kent system 1915 models; Connecticut system 1916 models; and Heinze-Springfield starting, lighting, and ignition system 1917 models. Maximum advance in all cases approximately 30°.

Reo

1910–17 Fours. F.O. 1- 3- 4- 2.

1915–17 Sixes. F.O. 1- 4- 2- 6- 3- 5.

1910–15, Four-Cylinder Models. Magneto setting, ½ inch before upper dead center, with spark lever in fully retarded position; maximum advance 5½ inches.

1916–17, Four-Cylinder Models. Magneto setting, upper dead center; maximum advance 6¼ inches.

1915, Six-Cylinder Model. Magneto setting, 1 inch before upper dead center; maximum advance 7½ inches.

1916–17, Six-Cylinder Models. Magneto setting, upper dead center; maximum advance 8½ inches. All measurements are on the periphery of the flywheel; 1 inch on the latter is equivalent to 7.10°.

Ross

Eights. F.O. 1R- 2L- 5R- 6L- 7R- 8L- 3R- 4L.

Battery ignition.

Saxon

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Scripps-Booth

Fours. F.O. 1- 3- 4- 2.

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Simplex

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Singer

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting; extreme retard, top dead center.

Spaulding

Fours. F.O. 1- 3- 4- 2.

Models CP and CS, Remy magneto; Model E, Bosch magneto; Model G, Eisemann magneto; Models H and I, Simms magneto; magneto settings; extreme retard, dead center.

Sphinx

Fours. F.O. 1- 3- 4- 2.

Battery ignition.

Standard

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Ignition setting point, magneto contacts just opening with piston 2 inches (on flywheel) past dead center at full retard; maximum advance 25°.

Stearns

1912—14 Fours. F.O. 1- 2- 4- 3.
1915—17 Fours. F.O. 1- 3- 4- 2.
1913—15 Sixes. F.O. 1- 5- 3- 6- 2- 4.
1916—17 Eights. F.O. 1R- 8L- 3R- 6L- 4R- 5L- 2R- 7L.

All the above have the Knight motor.

1915—17. Magneto setting, with the spark lever fully retarded, is 1½ inches past dead center, as measured on the flywheel.

On all other models, the magneto setting point is upper dead center; maximum advance in all cases is approximately 30°.

Studebaker

Model 20. Fours. F.O. 1- 2- 4- 3.
All Other Fours. F.O. 1- 3- 4- 2.
All Sixes. F.O. 1- 5- 3- 6- 2- 4.

All Four-Cylinder Models. Ignition setting point is 4 inches before upper dead center, as measured on the flywheel. All Six-Cylinder Models. Ignition setting point is 5⅛ inches before upper dead center, as measured on the flywheel.

Stutz

All Four-Cylinder Models. F.O. 1- 3- 4- 2.
All Six-Cylinder Models. F.O. 1- 4- 2- 6- 3- 5.

Sun

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Thomas

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Ignition setting point, magneto contacts opening ½ inch on travel of piston before upper dead center at full advance.

Trumbull

Fours. F.O. 1- 3- 4- 2.

Fixed ignition setting.

Velie

1916–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Ignition setting point, upper dead center with spark lever fully retarded.

Westcott

1910–14 Fours. F.O. 1- 3- 4- 2.

1913–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1910–14. Remy and Bosch magnetos; ignition setting point, upper dead center.

1914 Fours. Atwater Kent system, upper dead center.

1913 Sixes. Bosch magneto; ignition setting point, with spark lever fully retarded, 1⅛ inches late, or past dead center.

1915 and later Sixes. Delco ignition.

Willys-Overland

All Four-Cylinder Models. F.O. 1- 3- 4- 2.

All Six-Cylinder Models. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting point, with spark lever fully retarded, ¾ inch to 1¼ inches late, or past dead center; maximum advance 30° to 35°.

Winton

Since 1907. Sixes. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting point with spark lever fully retarded, upper dead center.

Wiring. *Necessity for High-Tension Cables.* Mention has been made of the fact that in early days much trouble was experienced with poorly insulated and poorly mounted wires. This was particularly the case with the secondary circuits, the insulation of which was frequently inadequate to carry currents at the high potentials employed, so that there was more or less leakage. This was further aggravated by the chafing, or rubbing, of these wires against moving parts. The former trouble was eliminated by the adoption of specially constructed cables which are tested to carry 30,000 volts. Cables of this type are illustrated in Fig. 111, which also shows the cables employed for electric lighting and starting installations, where the chief difficulty has usually been the selection of a cable of too small a carrying capacity for the current used.

The importance of using heavily insulated cables for both the primary and secondary cables of the ignition, and, more particularly the latter, has come to be generally understood, and cables especially designed for this service have now been in use for a number of years; but the importance of using wiring of ample capacity, in the lighting and starting circuits, is not so well appreciated. In the former instance, the problem was one of insulation only, the amount necessary to prevent leakage of the secondary current not being fully realized in the early days; nor was the necessity for thoroughly protecting the primary cables from the effects of oil and water taken into account. Trouble from these sources, however, have long since been a matter of the past; even the well-insulated cables now in general use become oil soaked in time, but, when faulty ignition is thought to be due to them, they are promptly replaced.

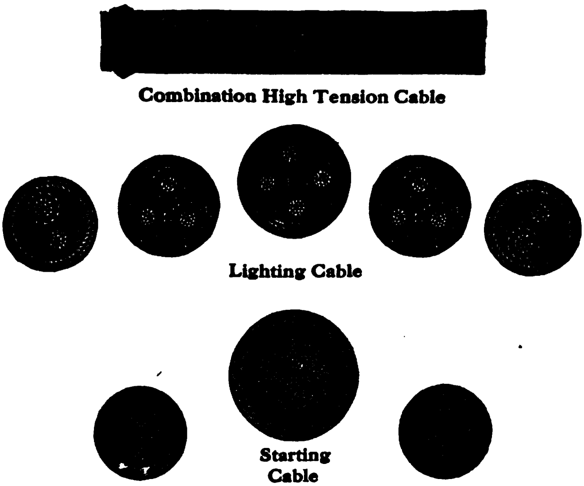


Fig. 111. Types of Cables Employed in Electrical Equipment of Automobiles

In many of the early electric starting and lighting systems, the wiring has been as poorly adapted to the purpose as was that of the pioneer ignition systems. This was not on account of improper insulation but owing rather to poor design or to a lack of consideration of the importance that proper wiring has on the efficient operation of the system. No electrical system of this kind is any better than its storage battery; and, as the amount of energy that can be husbanded in the latter is limited, every effort must be made to avoid waste in its use. What constitutes waste in a standard lighting system using current at 110 to 115 volts, and what may be so termed where the available potential is only 6 volts, are two very different things. A voltage drop of one to 5 volts in an incandescent lighting system is negligible. A drop of 5 volts below the 110-volt standard will cause a perceptible dimming of the lamps, but the life of the lamp filaments themselves will be greatly increased, other factors remaining the same, so that the loss in efficiency is not of such great moment.

Importance of Voltage Drop. But, in an electric starting and lighting system, the loss of even a fraction of a volt due to the wiring represents a substantial falling off in the power. As mentioned in the introductory, the unit of potential, or voltage, times the unit of current flow, or ampere, equals the watt or power unit, and there are 746 watts in an electrical horsepower. Take the case of an electric-starting motor with an unusually long connection between the battery and the electric motor. Assuming that the length and diameter of this wire is such that there is a loss of *1 volt* between the battery and the motor and that, at the moment of starting, 300 amperes are required to *break away* the engine, i.e., free the pistons and bearings when the lubricating oil has thickened from the cold so as to bind them. In the actual power consumed, this voltage drop represents 300×1, or 300 watts, equivalent to more than $\frac{3}{7}$ horsepower.

The loss of but $\frac{1}{2}$ volt, other factors remaining the same, is equivalent to almost $\frac{1}{6}$ horsepower, or about what a strong man can exert for a limited time. This appears to be getting things down pretty fine, but in the case of the Dyneto system, the manufacturers specify that the cable between the starting motor and the storage battery must be large enough to transmit *400 amperes with a total loss not to exceed $\frac{1}{4}$ volt.* With this amount of current, the voltage drop in question represents 100 watts, or nearly $\frac{1}{7}$ horsepower. Of course, this loss only takes place at the instant of starting, but that is just the time when the highest efficiency and the full power of the battery is required. Moreover, the starting motor frequently has to be operated a number of times, especially in cold weather when the battery efficiency is at its lowest, before the engine will start. Even at the lower-current values necessary for turning the engine over after it has been broken away, a drop of one volt represents an appreciable power loss, as the current consumed is anywhere from 50 to 100 amperes. It will be apparent from this why the manufacturers lay such emphasis on their instructions not to lengthen connections, if avoidable, and then only to use wire of the same size and kind. This, of course, does not apply to the starting motor connection, as that should never be lengthened without increasing the diameter of the wire to compensate for the increase in length.

Calculating Size of Cable. It is not advisable to do so where it can possibly be avoided, but, when made necessary by the fitting of an enclosed body, the following formula should be used for calculating the size of cable that should be employed:

$$\frac{\text{Maximum current} \times 10.7 \times \text{number of feet of wire}}{.25} = \text{diameter or cross-section of wire in circular mils}$$

For example, in the case cited above, where the maximum current at the instant of starting is 300 amperes and the distance between the battery and the starting motor is four feet (measured from battery to switch and from the latter to the starting-motor terminal), the size of wire necessary would be:

$$\frac{300 \times 10.7 \times 4}{.25} = 48{,}960 \text{ circular mils}$$

As shown in the table on page 27, which gives the corresponding sizes of the B & S gage, the nearest to this is No. 3 wire of 52,634 circular mils cross-section, but, to allow for a factor of safety, either a No. 2 or a No. 1 wire would be used for such an installation. Now, in case it becomes necessary to take the battery from the running board close to the engine and place it under the floor of an enclosed body, increasing the length of wire needed to 8 feet, the cross-section of the wire required would be 98,720 circular mils, the closest gage number to this being the No. 0 cable. In other words, doubling the length of the cable would make it necessary to double its cross-section in order to prevent exceeding the minimum permissible drop in the voltage. This will make plain why some of the amateur experiments in re-locating the essentials of an electric starting system have had such disastrous effects on its efficiency.

Effect on Lights. In the case of the lamps, the effect of an increased drop in the voltage is not so serious; though, because of the very low-battery voltage available, what would otherwise be a negligible loss assumes important proportions. On the 3-cell 6-volt battery now so generally used, the lamp filaments are designed to burn to full brightness on a potential of 6 to 8 volts, this variation being provided to compensate for the difference in the battery voltage when fully charged and when partly discharged, as the voltage of the battery decreases as it discharges, dropping to but 1.50 volts per cell when practically exhausted, or a total of 4½ volts. Even if receiving this full voltage, the 6-volt bulbs would burn very dimly, but there must be deducted from it the voltage drop due to the wiring and the switches. This is the reason why the brightness of the lamps (with the generator idle) affords such an excellent indication of the state of charge of the battery.

It will be apparent from the above that a drop in potential of but one volt in the lighting circuit would cause a serious loss of efficiency at the bulbs. Assuming that the headlights consume 4 to 5 amperes, and applying the above formula on the basis of a maximum distance of 10 feet from the battery, it is found that a No. 16 wire is necessary; but, in order to provide a large factor of safety, nothing smaller than No. 14 wire is ordinarily employed for the lighting circuits, and, in some cases, it is No. 12.

Importance of Good Connections. Under the head of "Resistance", however, attention has been called to the fact that not alone the length and size of the connecting wires, but also all switches and joints are factors in calculating the total resistance of a circuit. Consequently, it is poor practice ever to make a joint in a wire where a single length may be employed. Whenever a wire is broken by accident, the trouble should always be remedied by replacing it with an entirely new piece rather than by making a joint in the old wire. Loose connections also add greatly to the total resistance in a circuit, as well as connections in which the contact faces of the terminals are dirty or corroded. In replacing or tightening connections, care should be taken to see that the parts in contact are scraped or filed bright and that both the terminal nut and its lock nut are screwed down firmly. The switches are also an important factor where voltage drop is concerned and switch blades or contacts that are dirty or corroded, or that are not held firmly in contact when closed, will be responsible for an appreciable drop in the voltage that will become increasingly perceptible as the battery becomes discharged.

Magneto Mounting. As the magneto is timed exactly with the motor, it must be positively driven synchronously with it at a speed depending upon the number of cylinders. This is crankshaft speed on a four-cylinder and one and one-half times crankshaft speed on a six. It has become standard practice to a very large extent both here and abroad to mount the magneto on a "pad" or shelf attached to the crankcase and drive it from a special auxiliary shaft, usually also utilized for driving the water pump or other motor auxiliary. Variations from this are to be found in the Renault and a few other European as well as American cars, in which the magneto is mounted at the forward end of the motor and driven by a cross-shaft and helical gears directly from the crankshaft of the motor. The only advantage of this is slightly greater accessibility. In any case, the magneto is not permanently fastened but is simply held on its support, against movement, by dowel pins in the base and a strap clamp tightened with a thumb nut, as shown in Fig. 112, which may be regarded as typical of American practice. As the efficiency of the magneto depends to a considerable extent on the very limited clearance between its armature and the pole pieces of the field, usually termed the armature tunnel, precautions are taken to avoid placing any stress on it that could tend to disturb this accurate alignment. The driving shaft is accordingly provided with a universal joint, the long familiar Oldham coupling being much used in this country for the purpose. On the Pierce-Arrow a leather disc universal drives the magneto and also cushions the armature.

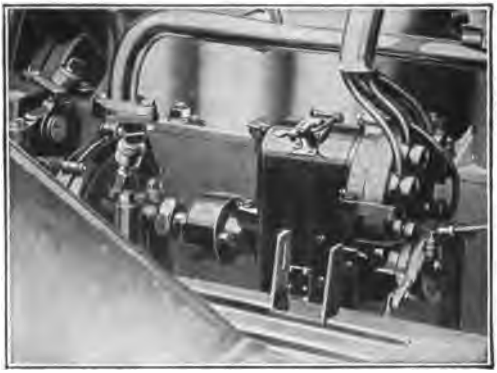
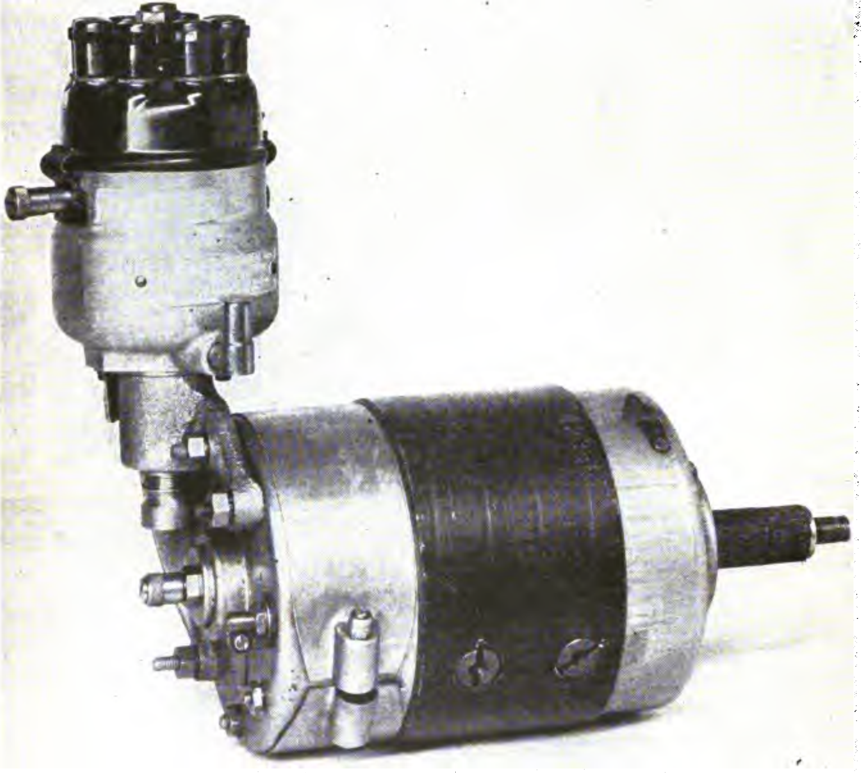


Fig. 112. Mounting of Magneto on Lozier Car



DELCO IGNITION GENERATOR USED ON COLE AND OLDSMOBILE EIGHT-CYLINDER CAR

Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART III

IGNITION—(Continued)

MODERN BATTERY IGNITION SYSTEMS

Effect of Starting and Lighting Developments on Ignition. Prior to the advent of the electrical starting and lighting systems, the magneto had reached a degree of development that appeared to leave not the slightest doubt as to its representing the ultimate type of ignition current generator. With the installation of a direct-current generator capable of supplying more than enough current for lighting and starting the car and charging a storage battery of high capacity, however, it appeared that there was a duplication of electrical apparatus for which there was no good economic reason. In other words, with such an ample and reliable source of current on the car as that presented by the charging generator and storage battery, why continue the magneto? There is no sound reason why one electrical system should not combine all three functions of ignition, lighting, and starting, and this has been successfully carried out on the Cadillac for several years past, while the Reo and other makes have more recently followed suit.

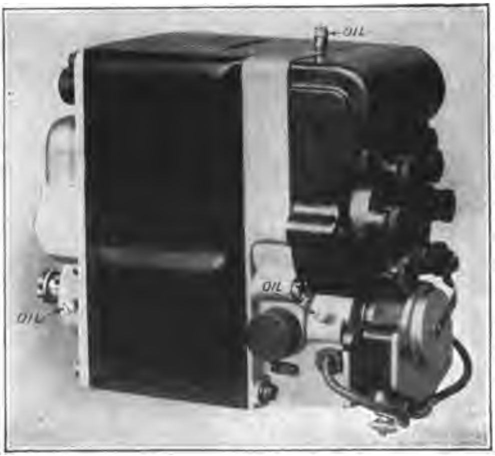


Fig. 113. Westinghouse Generator with Ignition Distributor

Generator Design Follows Magneto Precedent. Several generator designs have been developed which resemble that of a magneto. In the Westinghouse generator, Fig. 113, and the Remy, Fig. 114, their contact breakers are of the magneto type, as will be plain from the Remy, Fig. 62, and the Westinghouse, Fig. 115, to cite but two examples of a number. In the case of the Westinghouse, the objection previously held against battery ignition—that it required much more manipulation of the spark advance lever to obtain efficient motor running—has been overcome by the provision of a centrifugally operated automatic advance device, Fig. 115, similar in principle and results to the Eisemann and Herz devices, Figs. 102 and 105, though differing from them in construction. The distributors employed are practically identical with those used on magnetos, but all resemblance disappears when the machine is dismantled, Fig. 116, revealing a compact direct-current generator.

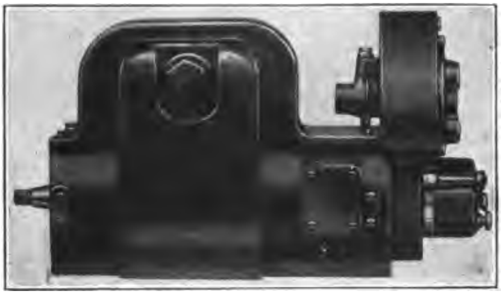


Fig. 114. Remy Combination Lighting and Ignition Generator

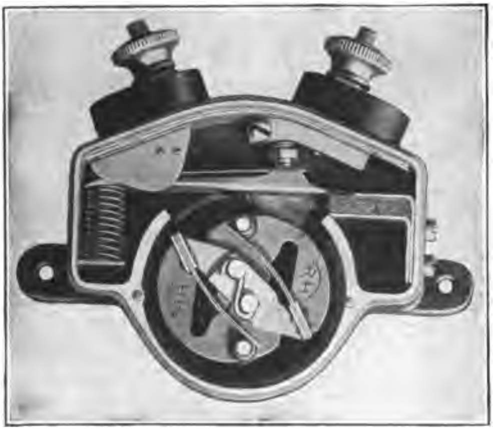


Fig. 115. Westinghouse Contact Breaker with Automatic Spark Advance

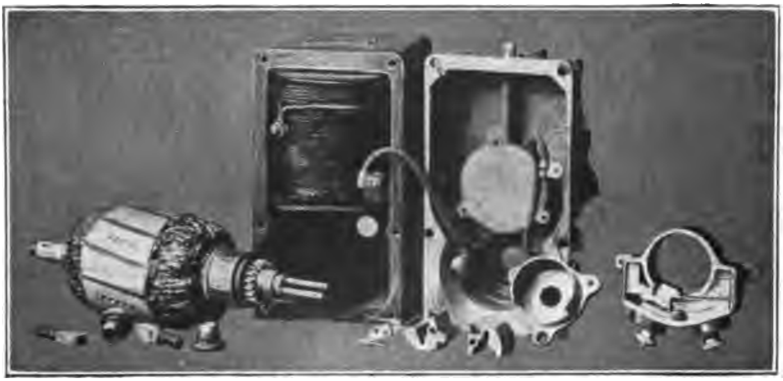


Fig. 116. Details Westinghouse Lighting and Ignition Generator

TYPICAL ARRANGEMENTS

Westinghouse Ignition Unit. This is a combination of all the essentials of magnetic ignition, i.e., the interrupter, distributor, induction coil, and condenser, brought together in a compact unit adapted for mounting either on the lighting generator itself or directly on the engine. It supersedes the type of ignition and lighting generator previously described and which now will be found only on cars of earlier models. As will be noted in Fig. 117, its components are the counterparts of the same essentials on the magneto, except that the interrupter cam has four lobes, so that no further description is necessary.

Fig. 118 is a wiring diagram of the connections. The interrupter and condenser are located at the bottom of the housing with the induction coil above and the distributor at the top. To prevent an excessive amount of current passing through the ignition unit, a

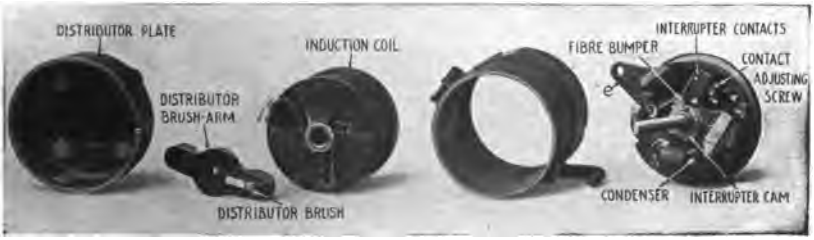


Fig. 117. Details of Westinghouse Ignition Unit
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

"ballast resistor" is connected in series with it. This is a resistance unit which, in the various models, is combined either with the switch or with the fuse box, or may be mounted independently. In case this resistance unit should become inoperative for any reason, the car may be run by replacing it with a standard 5-ampere fuse cartridge. A fuse of larger capacity than this should not be used and the car should not be run any longer than absolutely necessary with the fuse in place, as the interrupter contacts would be badly burned. The working of the interrupter contacts may be inspected by loosening the set screw at the bottom of the housing and lifting the distributor an inch or so, Fig. 119.

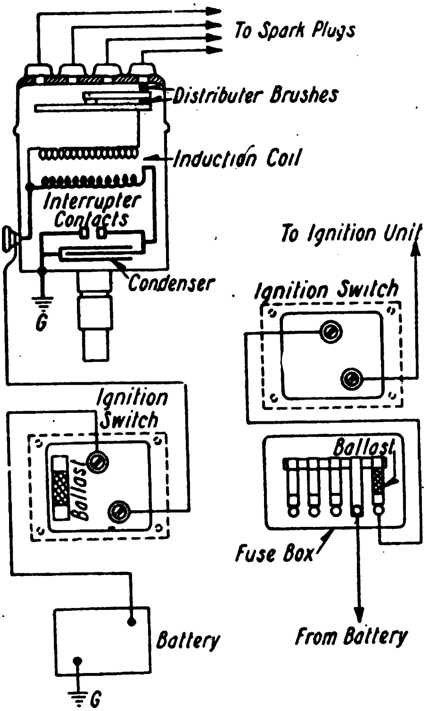


Fig. 118. Wiring Diagram for Vertical Ignition Unit. Left—with Ballast on Rear of Ignition Switch; Right—with Ballast in Fuse Box

Atwater-Kent System. The Atwater-Kent system is based on a "single spark" interrupter and was the pioneer in making battery ignition successful on the modern automobile before the advent of the perfected lighting generator, the current source usually being a dry-cell battery. It was considered an advantage in earlier years to produce a series of high-tension sparks in the cylinder on the theory that, if the first failed to explode the charge, it would be fired by the subsequent sparks. The fallacy of this long since became apparent and the reason therefor has been dwelt upon already. The Atwater-Kent interrupter is typical of devices of this class which have been developed since and as it is fitted on thousands of cars which come to the repair man's attention at one time or another, a detailed description of its working is given here.

Operation of "Unisparker". The ratchet *A*, Fig. 120, has as many notches as there are cylinders to be fired. It is mounted on the central vertical shaft of the device which also carries a distributor, and in this combined form is known as a "Unisparker". On four-cycle engines it is driven at half crankshaft speed, and at crankshaft speed on two-cycle engines (motor boats). The ratchet *A* engages the lifter *B*, and, as *A* rotates, its teeth or notches successively tend to draw *B* with them, against the tension of the spring *C*. In doing so, the head of *B* strikes the swinging lever or "hammer" *D*, whose motion in both directions is limited as shown, and the hammer communicates the blow to the contact spring *E*, bringing the contact points together momentarily. *E* is a compound spring, the straight member of which carries the movable contact, while the stationary contact *F* is mounted opposite it. The second member of this compound spring is curved at its end to engage the straight member. Ordinarily the straight spring blade is held under the tension of the curved blade and the contact points are held apart.

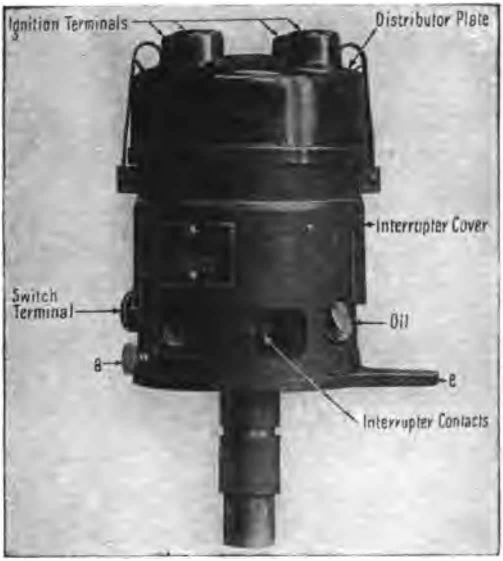


Fig. 119. Westinghouse Ignition Unit with Interrupter Cover Raised Showing Interrupter Contacts
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

When the curved blade is struck by the hammer *D* the points contact. The curved blade, however, is thrown over farther by the impact and its hook leaves the straight blade. Upon reaching the

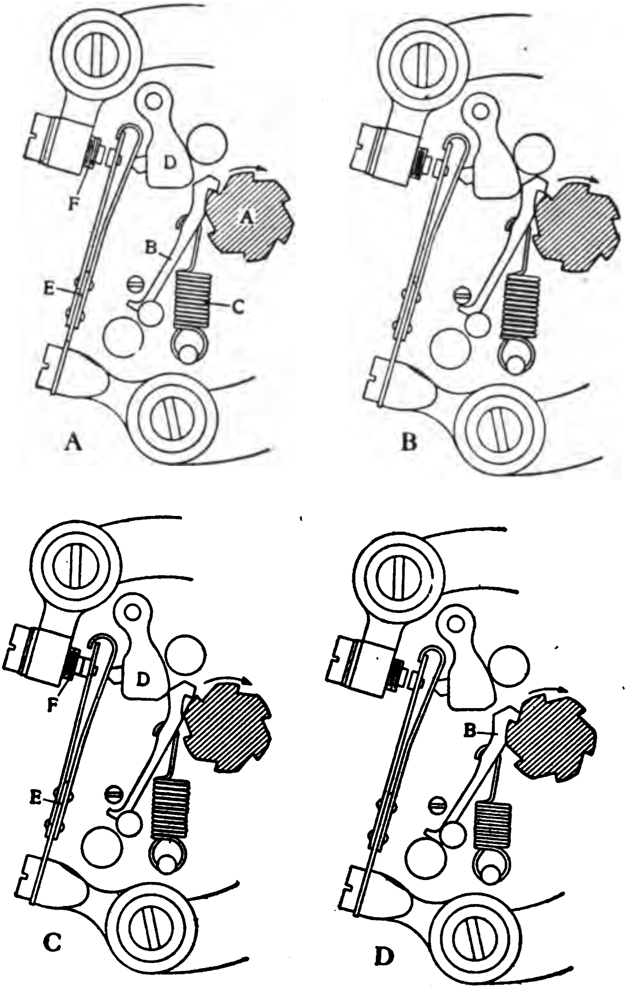


Fig. 120. Diagram Showing Operation of Atwater-Kent Interrupter
Courtesy of "The Horseless Age"

limit of its movement it flies back and strikes the end of the straight blade a blow causing a very sharp break of the circuit. This movement is so extremely rapid that it cannot be detected by the unaided eye, so that its working cannot be tested simply by watching the operation of the contacts as in the case of a magneto interrupter. *B*, *C*, and *D*, of Fig. 120, show the successive movements of the parts during a single phase. In *A*, a notch of the ratchet has engaged *B* and is drawing it against the tension of the spring *C*. In the second sketch *B*, the hook is released. In *C*, the lifter is riding back over the rounded portion of the ratchet and striking the hammer *D*, which in turn pushes *E* for a brief instant against *F*. The return of *B* to the position shown in sketch *D* is so rapid that the eye cannot follow the movement of the parts *D* and *E*, which to all appearances remain stationary.

Adjustment of the contact points is made by removing one of the thin washers from under the head of the contact screw *F*, and the gap should be .010 to .012 inch, never exceeding the latter. Where more accurate means of determining this distance are not available, it may be gaged with a piece of manila wrapping paper which should be perfectly smooth. With the aid of a "mike" (micrometer) a sheet of paper of the proper thickness can be selected. The contacts are of tungsten and as the moving parts are all of glass-hard steel, very accurately machined, the wear is negligible so that adjustment is not required oftener than once in 10,000 miles running and replacement only after 50,000 miles.

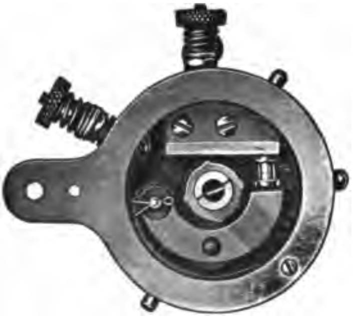


Fig. 121. Connecticut Interrupter

With this interrupter it is impossible to run the battery down by leaving the switch closed inadvertently, as the contacts are never together when the moving parts are idle. The remainder of the system comprises an induction coil (nonvibrator) and a high-tension distributor.

Connecticut Battery System. While this system also employs a single-spark interrupter, it is what is known as a "magneto type", and the similarity to those employed on magnetos for the same purpose will be noted in Fig. 121. A characteristic of this type of interrupter is that its contacts normally remain closed so that if the ignition switch is left on, the battery will be run down. To prevent this in the Connecticut system, an automatic switch acting on the thermoelectric principle is employed. The interrupter consists of a semicircular arm of sheet steel to make it light. This is pivoted at one end, carries a roller at its center and the movable contact at the other end. It is insulated from its pivot and the roller is of fibre. The vertical bindingpost is electrically connected with the stationary contact and the second one, at an angle, connects with the movable contact. While an interrupter of this type has practically no lag, means of advancing the moment of ignition are provided (lever extension at left), as the spark must occur earlier at high engine speeds to permit of propagating the flame throughout the charge in the extremely short time available in the modern high-speed engine. As the contacts are opened only momentarily, the interrupter is in circuit most of the time and accordingly is not economical of current, so that it is designed only for use with the battery and generator of the lighting and starting system.

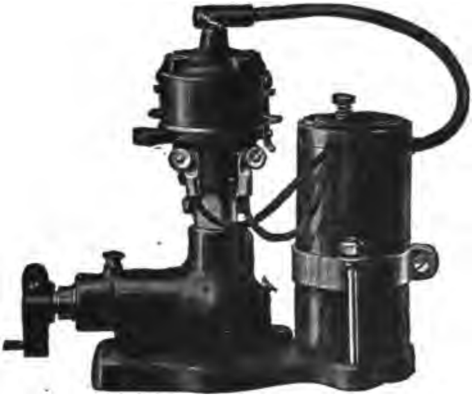


Fig. 122. Connecticut Igniter Complete Except for Switch
Courtesy of Connecticut Telephone and Electric Company, Meriden, Connecticut

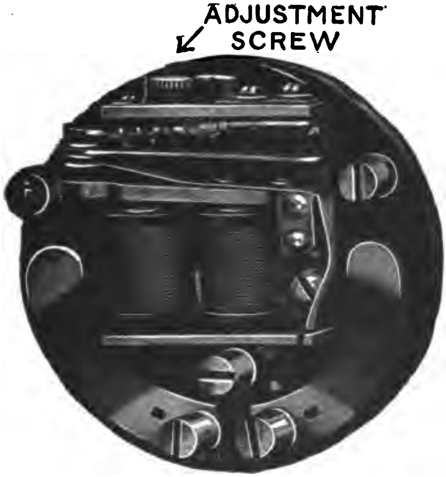


Fig. 123. Connecticut Automatic Switch

Fig. 122, shows the complete Connecticut system (minus the switch) as designed for mounting on a magneto bed plate. The distributor is mounted over the interrupter, while the coil is at the

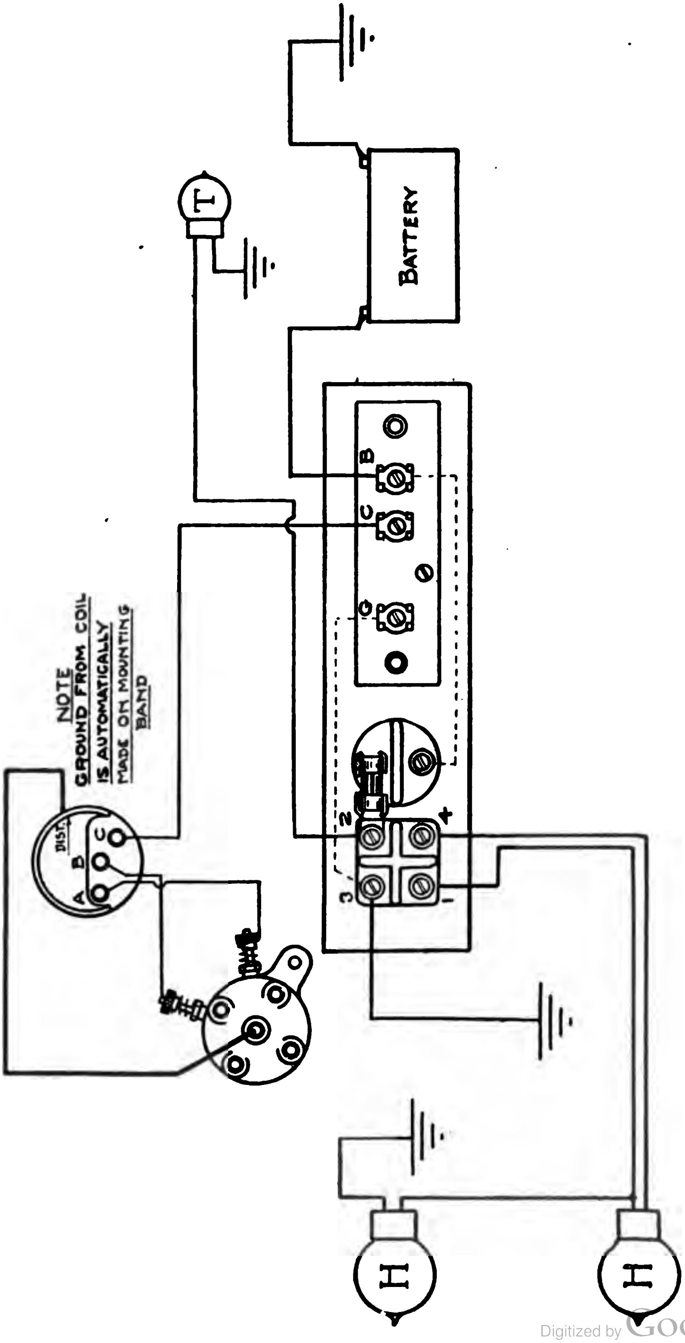


Fig. 124. Wiring Diagram for Connecticut Ignition System

right. The primary of the coil is not grounded, insulated leads being connected to the two binding posts of the interrupter, as shown. The grounding of the secondary winding of the coil is effected through the metal holding band and the bolts fastened to the bed plate. A glass tube is employed to house the safety gap which is mounted under the cover of the coil.

Automatic Switch. The purpose of the automatic switch, Fig. 123, is to open the circuit in case the switch button has been left on with the car stopped. The current passing with the contacts closed, when the engine is idle, is much greater than when it is constantly being interrupted by the rapid-fire action of the cam, but, unlike a circuit-breaker, the device is not designed to act instantly upon the passing of an overload current as this would prevent cranking the motor. The device consists of a thermostatic arm regulated by the adjustment screw at the top of the figure, an electromagnetic vibrator the armature of which carries a hammer, and the necessary connections. Current enters at either the right- or left-hand screw at the bottom, according to whether the switch is closed at the end of the sectors at the right or left of the figure (*M* or *B* on the switch cover plate), and flows through the heater tape on the arm of the thermostat to the screw at the upper right in the figure. This heater tape is a resistance that becomes warm upon the passage of a certain amount of current for a short time and, with an increase in temperature, causes the arm of the thermostat to bend until it makes contact with the upper thermostatic arm. This puts the windings of the magnet in circuit through the post just below the magnet coils and sets the vibrator in motion, causing the hammer on the armature to strike the switch button and open it. Fig. 124 is a typical wiring diagram in connection with the lighting system, the automatic switch being combined with the lighting switch.

Remy System. The relation that the various essentials of a battery-ignition system of the types here described bear to each other is made clear by glancing at the graphic wiring diagram of the Remy system, Fig. 125. The starting switch shown at the left has, of course, no connection with the ignition system but is included in the illustration because the current-supply wire for the latter is connected to one terminal of the starting switch instead of being taken directly to the battery. This is done simply to save wire. The source of current supply is the storage, and, as is the case with all one-wire systems, one side of the battery is grounded, as shown. Similar ground connections, necessary to complete the circuit, will be noted at the various units of the system. The colors mentioned in connection with the various wires are those of their insulation, which serves to identify them.

Detecting Grounds. All current used by the ignition system passes through the ammeter, which thus serves as a method of detecting grounds. For example, if, with the engine idle and all lamps turned off, the ammeter registers a discharge, it indicates a leak in the system. By disconnecting the wires leading to the lamps, relay, and ignition switch in turn, the particular part of the system in which the fault lies may be detected. If, for instance, the ammeter needle immediately drops back to zero upon disconnecting the lead to the ignition switch, it indicates that the leak is in some part of the ignition system; if it still indicates a discharge after disconnecting this lead, it shows that the leak is in one or the other of the two remaining parts of the system to which the wires in question lead, and it may be found by continuing the process of elimination further. Should the ammeter still show a discharge reading after disconnecting

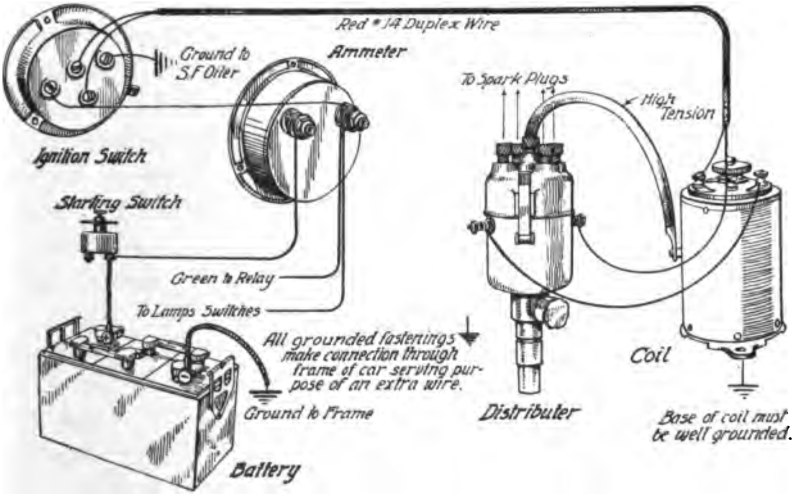


Fig. 125. Essentials of Battery Ignition System

all three of these wires, the trouble would lie either in the starting switch or in the cable connecting it with the battery. This could be proved by disconnecting the switch from the battery and running an independent lead from the battery to the ammeter, temporarily. There is always a possibility, of course, that the fault may lie in the ammeter itself. A current-measuring instrument is necessarily of delicate construction and is apt to suffer from the vibration and jolting. Before carrying out all the above tests, make certain that the ammeter needle has not become stuck.

Ignition Switch. From the ammeter, Fig. 125, the current passes to the ignition switch of the *reversing* type, that is, it serves to change the direction in which the current flows every time it is turned on. For the purposes of either ignition or lighting, it is immaterial in which direction the current flows, but the latter has an important bearing on the life of the expensive contact points in the interrupter. As has been explained previously, the passage of a current through contact points or across a gap tends to transfer the material of the positive electrode to the negative, resulting in the formation of a cone at the positive and a crater, or hollow, at the negative. When the points have worn to this condition through long service, the contact is poor and uncertain, while the points are apt to stick, and to put them in good working order means filing away some of the platinum which is more costly than gold. The use of a reversing switch, which alternately makes the same point positive and negative, keeps both contacts in better condition for a greater length of time.

One side of the ignition switch is grounded on the oiler, through which the current passes to the frame to which the oiler or its support is attached. This particular connection is merely a matter of convenience and is only another instance of saving wire. The wiring diagram in question shows the installation of the Remy system on the Scripps-Booth four-cylinder chassis; on other machines, the ground connection will usually be found in some equally convenient point close to the switch. The two remaining connections from the ignition switch run to the coil and the interrupter, or contact breaker, respectively, and complete the primary circuit.

Interrupter and Distributor. The interrupter is enclosed in the same housing as the distributor, Fig. 125, and is directly below it. As with a magneto, the coil is grounded by attaching it to its pedestal on the car, the plate shown serving as a ground connection for one side of both the primary and the secondary windings of the coil. Consequently, but one connection for the primary circuit and one for the secondary circuit need be made from the coil to the interrupter.

By tracing the connections just described, it will be plain that when the contacts of the interrupter are closed, current flows from the battery through the primary of the coil. The revolving members of both the interrupter and the distributor are mounted on a vertical shaft driven by helical gearing from one of the half-time shafts of the engine. When the cam on this shaft opens the contact points of the interrupter, the primary circuit is suddenly broken, and a high-tension current is induced in the secondary winding of the coil. As the revolving member of the distributor is timed to make contact with one of its stationary segments every time the contacts of the interrupter open, the secondary current is led to one of the spark plugs. The occurrence of the spark at the plug is practically simultaneous with the opening of the interrupter contacts.

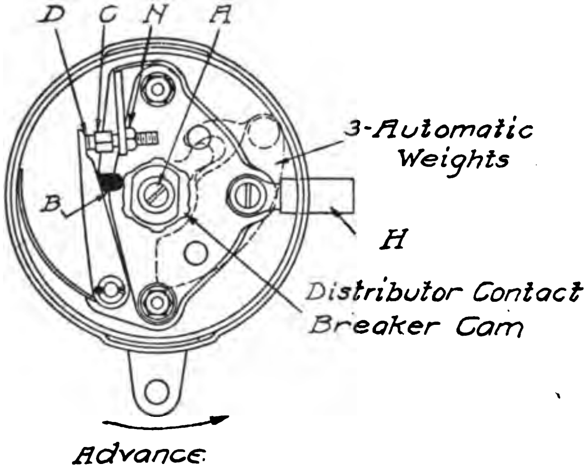


Fig. 126. Delco Magneto Type Interrupter

Delco System. A magneto-type interrupter, substantially similar to that of the Connecticut system except that it is provided with an automatic-spark advance, is used, as shown in Fig. 126. The arm *B* carries the movable contact *D* and a fiber-striking lug which bears against the four-part cam and is lifted by its revolution against the tension of the leaf spring held against the inner wall of the housing. The stationary contact is at *C* and is adjusted by means of the screw and locked in place by the nut *N*. These contacts should be so adjusted that when the fiber block on *B* is on top of one of the lobes of the cam, the contacts should open sufficiently to allow the gage on the distributor wrench, provided with the system, to close the gap. As in the Connecticut interrupter, the contacts normally remain closed, being opened momentarily by the cam, which has as many projections as there are cylinders to be fired. This is the later model of Delco interrupter (1916).

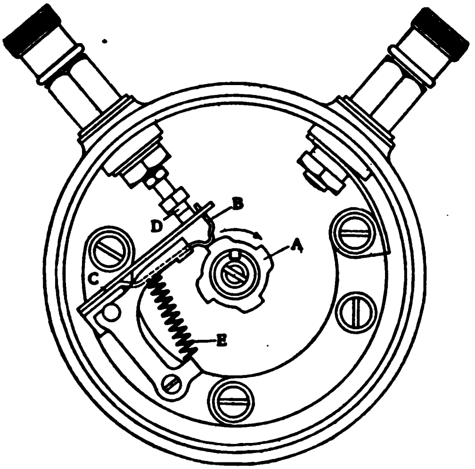


Fig. 127. Diagram of Earlier Model of Delco Interrupter

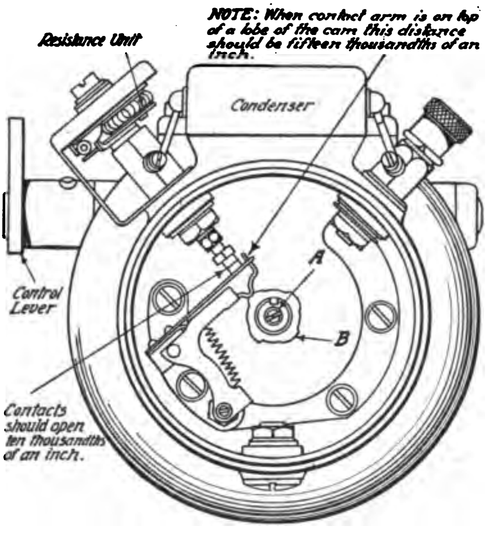

NOTE: When contact arm is on top of a lobe of the cam this distance should be fifteen thousandths of an inch.
Resistance Unit
Condenser
A
B
Control Lever
Contacts should open ten thousandths of an inch.

Fig. 128. Delco Timer with Resistance Unit

Earlier Model Interrupter. In an earlier model which will be found on a great many cars, the contacts are normally held open, Fig. 127. The movable contact is carried on a straight spring blade to which is attached a bent spring blade *B* held against the cam by the spring *E*. The latter also places the spring *C* under slight tension and holds the movable contact away from the stationary contact *D*. When the projection of the cam strikes the raised portion of *B*, it deflects the latter and allows the contact points to come together. As it passes the bump on *B*, *E* draws *B* back sharply, its end strikes *C*, and the contacts are suddenly opened, the duration of the contact varying with the speed of the engine.

Timer with Resistance Unit. Mention has been made of the fact that the contacts of the interrupter in the battery system of ignition are normally closed, just as they are in the magneto interrupter, only the circuit being opened at this point at the time of ignition. Owing to the rapidity of their action and the extremely short interval between contacts in the interrupter of a high-speed engine, this calls for a very small current consumption. Should the ignition switch be left closed when leaving the car, however, the timer cam is just as likely to stop in the closed position as in the open, and this small steady discharge will result in exhausting the storage battery. To prevent this waste of current and possible damage to the contacts and coil, a later type of timer has been provided with a resistance unit. This is shown on the left-hand terminal of the timer, Fig. 128, which illustrates the type used on the Cole, among others. The unit

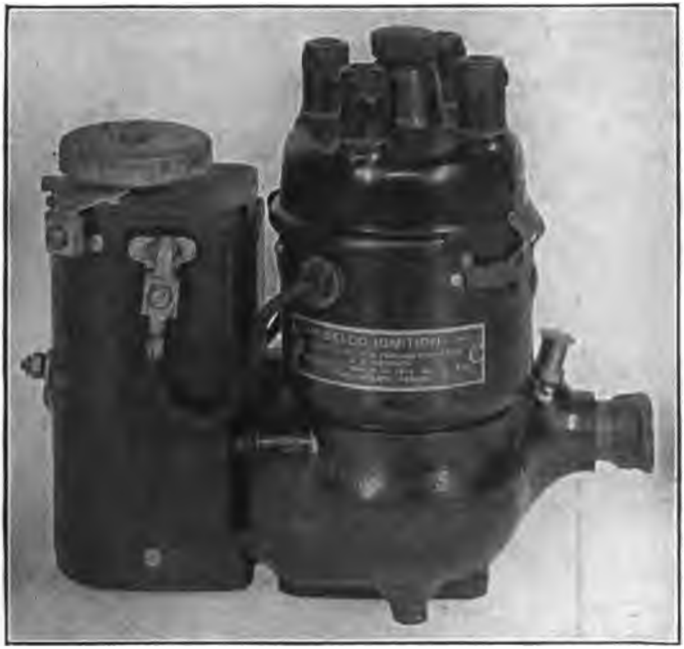


Fig. 129. Four-Cylinder Battery Ignition Unit on Dodge Car (1917)—Coil at Left
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

consists of a small open coil of high-resistance wire wound upon a porcelain spool mounted on the head of the terminal.

All the current passing through the timer must first pass through this resistance winding, but, owing to the extremely short period it continues between interruptions due to the opening of the contact points, the resistance wire remains cool. When the switch has been left on with the engine idle, however, the current is then continuous and of greater value, and it brings the resistance wire to a red heat in a comparatively short time. At this temperature, its resistance increases so greatly that it permits very little current to pass. It will also be noted that the condenser is mounted on the timer in this case.

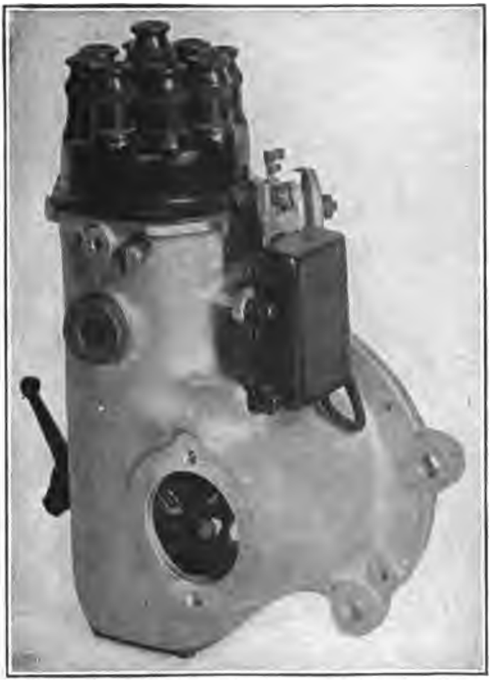


Fig. 130. Eight-Cylinder Distributor and Drive (Delco) as Used on 1917 Cadillac
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

As the spark occurs at the instant the timer contacts are opened, the ignition timing may be altered by moving cam *A* with relation to its shaft, which is done by loosening screw *B*. Turning the cam in a clockwise direction, or to the right, advances the time of ignition, and to the left, or counter-clockwise, retards it. The distributor used in connection with this timer is provided with automatic spark advance, as well as with the usual manual control on the steering wheel. Typical distributors for five-, eight-, and twelve-cylinder installations are shown in Figs. 129, 130, and 131, respectively, the first being found in the 1917 Dodge, the second in the 1917 Cadillac, and the third in the 1917 Haynes. In Fig. 132 is illustrated a dual-type timer having independent interrupter contacts for both the battery and the magneto. Apart from this feature, its construction is the same. This type is employed on the Oakland.

Delco Ignition Relay. As originally designed, the Delco ignition system was provided with a relay to produce a series of sparks for starting and a single spark when running. While this is no longer a part of the system, it is in use on thousands of cars now in service. The relay itself is shown in Fig. 133, together with a diagram of its connections. It consists of an electromagnet with two windings, one of coarse wire and one of fine wire, similar to a battery cut-out. The coarse winding produces a greater magnetic effect than the fine winding and exerts sufficient pull on the movable armature when at rest to draw it toward the end of the magnet core. It is so connected that the current ceases to flow through it when

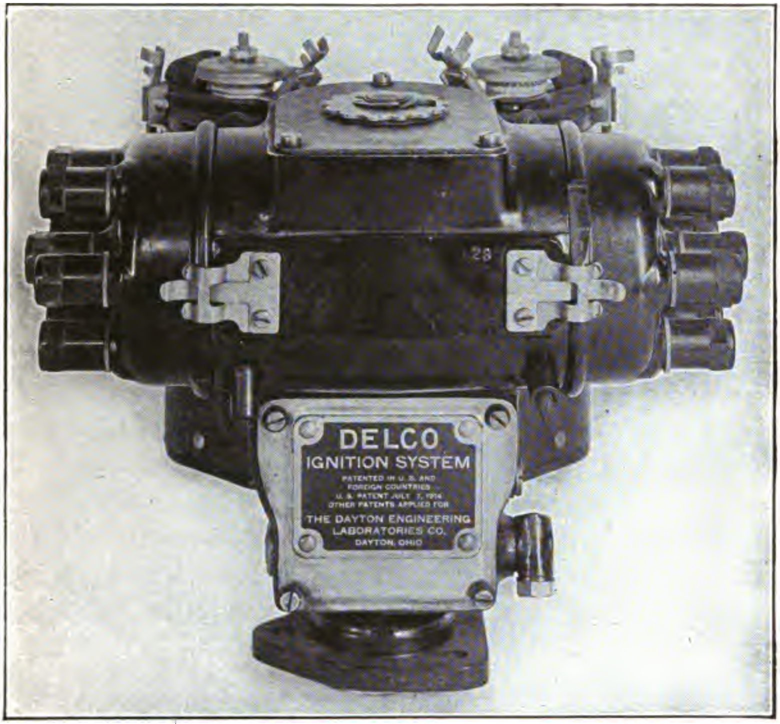
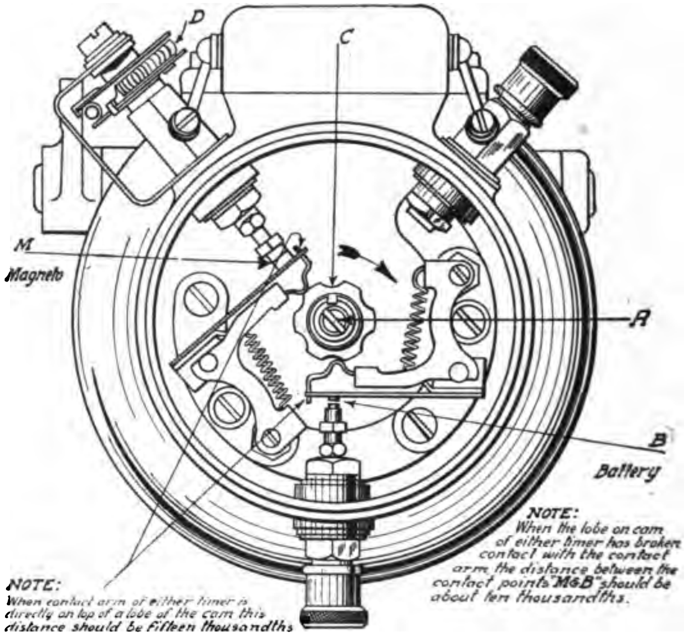


Fig. 131. Twelve-Cylinder Delco Distributor on Haynes (1917)
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

the contacts *C* are open. The fine winding is connected to the contacts so that it holds the armature of the relay open after the circuit of the coarse winding is broken at the contacts *C*, and is known as the "holding coil". Its magnetic pull is not sufficient to draw the armature down from its position of rest, but strong enough to hold it there after it has been pulled down by the other winding. A condenser is connected around the contacts *C* to suppress the arc and increase the speed of working. A three-way switch is provided, having a point for "starting", one for "running", and a neutral point. When on the starting point, the relay operates continuously, the same as a vibrator, and produces a series of sparks; on the running point, the fine winding of the coil is energized and the contacts held together, thus producing a single spark.



NOTE:
When the lobe on cam of either timer has broken contact with the contact arm the distance between the contact points "M&B" should be about ten thousandths.

NOTE:
When contact arm of either timer is directly on top of a lobe of the cam this distance should be fifteen thousandths

Fig. 132. Delco Dual Type Timer with Two Sets of Contacts

Interrupter for Higher-Speed Engines. For the extremely high-speed engines now coming into general use, a special interrupter having two sets of contact points and a three-part cam is employed (for six-cylinder motors). Each set of contacts is connected to a relay so that the circuit is closed through the two relays alternately,

Google

thus giving each magnetic interrupter more time in which to open and close the circuit. Fig. 134 illustrates the connections of a system of this type, the interrupter being shown just above the coil, while Fig. 135 shows the complete wiring diagram.

Adjusting Delco Ignition Relay. The ignition relay is connected in the dry-battery circuit and serves to interrupt the primary-ignition circuit, inducing a high-tension current in the secondary so that a spark will occur at the plugs.

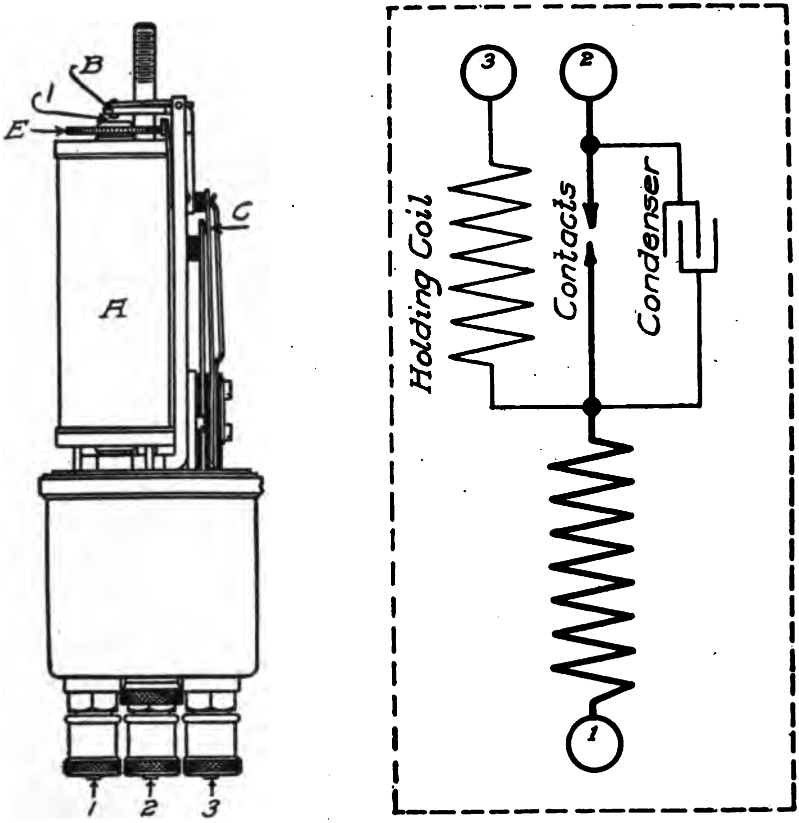


Fig. 133. Diagram of Delco Ignition Relay and Its Internal Connections
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

Methods of Connecting Relay. The relay is connected to the ignition coil and the distributor in two ways, as shown in Figs. 135 and 136. The operation of the relay, which varies slightly with its connection to the external circuit, is discussed as follows:

(a) (See Figs. 133 and 135 interchangeably.) The contacts *C* of the relay and the coil *A* are in series, with a special set of timer contacts on the dual distributor. When these contacts are closed (by the revolution of the fiber-timing cam), current passes through the ignition coil and timer contacts and contacts *C* of the relay and through the coil *A*, energizing the latter. This immediately causes the armature to open, thus interrupting the primary circuit and causing a spark at the plug. As soon as the circuit is interrupted, coil *A* is no longer energized and contacts *C* open again, this being repeated indefinitely as long as the timer contacts are together. This occurs only when the circuit between the terminals No. 6 and No. 7 on the combination ignition and lighting switch, Fig. 135, is open, which is accomplished by pushing the starting button. If it is desired to obtain but a single spark, as for running (the vibrating contact giving the repeated spark being simply for starting), the holding coil, Fig. 133, is energized so that when the armature touches the core, it is held there and a single spark, similar to that produced by generator or storage battery ignition, is obtained. This coil is energized when the terminals No. 6 and No. 7 on the combination switch, Fig. 135, are closed, which is accomplished by releasing the starting button.

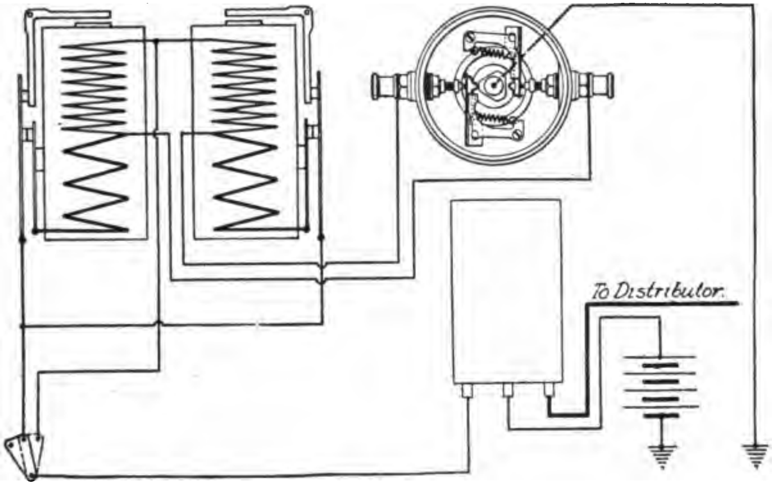


Fig. 134. Diagram of Delco Special Interruper for High-Speed Engines
Courtesy of "The Horseless Age"

(b) (See Fig. 136.) This is the method used in connecting the ignition relay on the Delco Junior system for 1914. The ignition switch completes the primary circuit, and, in this manner of using the relay, the holding-coil circuit is completed through the timer contacts. Therefore, a vibrating spark is obtained as long as the timer contacts are open, and the timing of this vibrating spark is obtained by the action of the contacts upon the holding coil itself.

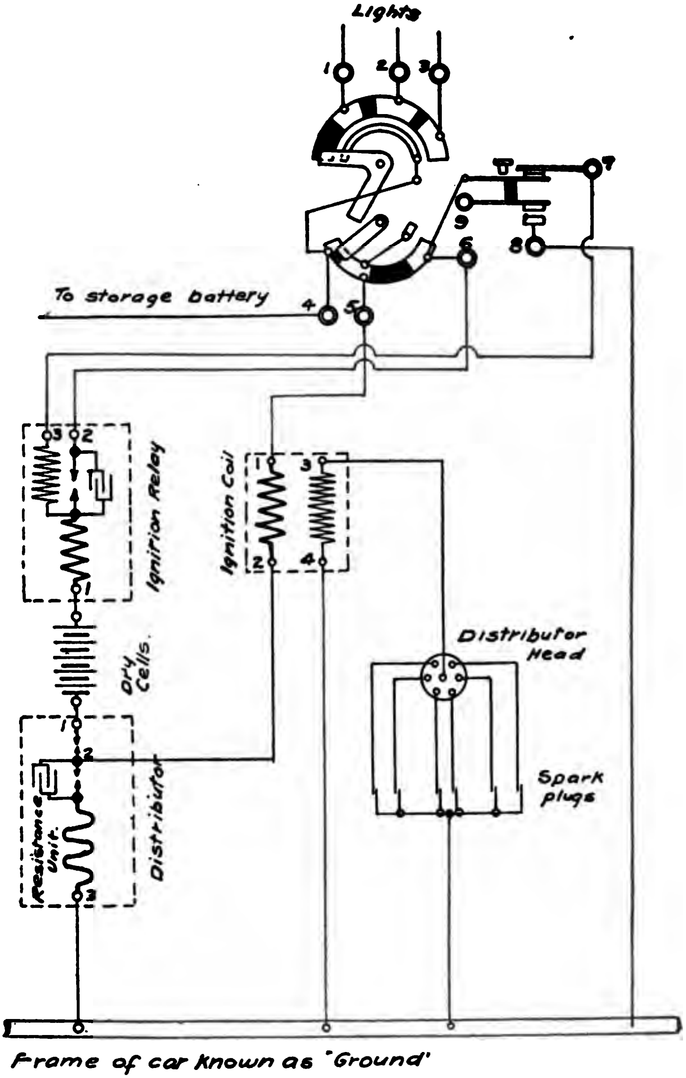


Fig. 135. Wiring Diagram of Delco Ignition System Using Relay

For this reason, this method of using the relay causes much later ignition than is obtained with the method described in the previous paragraphs.

Adjustments. The following points should be borne in mind when adjusting the relay: When the armature *B*, Fig. 133, is pressed

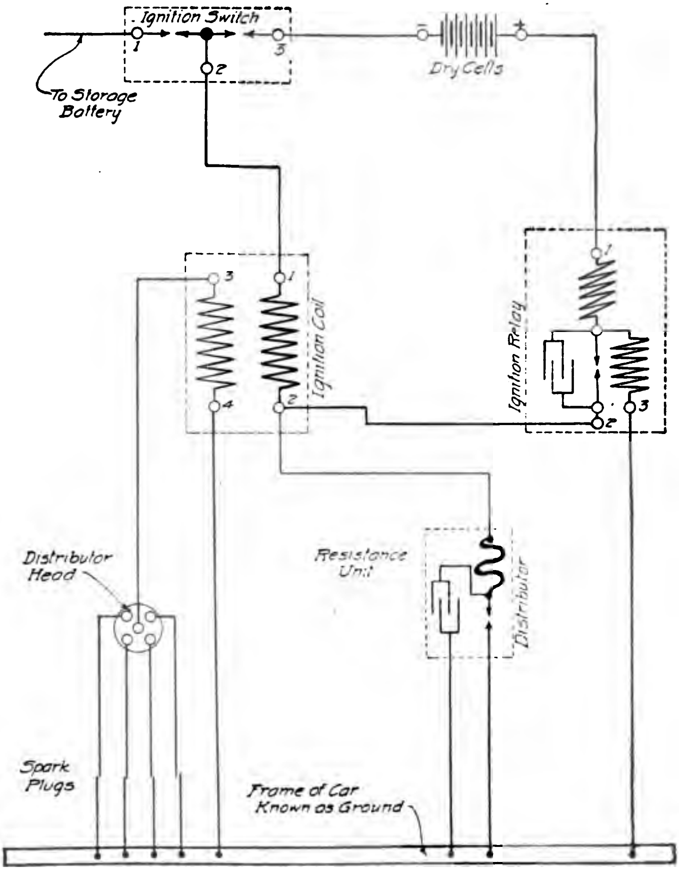


Fig. 136. Connections of Delco Ignition Relay

down with the finger, thus opening contact *C*, there should be absolutely no motion of the blade *G*, Fig. 137, carrying the lower contact. The gap at *C* should be approximately .005 inch (thickness of a piece of paper similar to, or slightly heavier than, that on which this book is printed). When blade *A* is lifted gently by hand, the contacts at *C* should open to the same gap as before, viz, .005. The points at *C* must make perfect contact.

There are two adjustments to the relay: the air gap at *I*, Fig. 133, which increases the distance at *C* also; and the tension exerted by the spring *A*, Fig. 137, on the contacts *C*. Slight adjustment of the air gap *I* may be made, but in no event should the distance between the contacts *C* be increased very much over the value mentioned above. If it is impossible to obtain a sufficiently powerful spark by adjusting the air gap slightly, it will be necessary to increase the tension of the spring *A*. This can be done by *crowning* the spring with a pair of duck-bill pliers. The spring is loosely held between the jaws of the pliers near the end at which it is screwed down to the relay frame, and the pliers are then moved along the spring with a downward pressure and a twist to the right, as indicated in Fig. 137. When properly carried out, this operation will cause the spring to assume a curve similar to that shown in the illustration, Fig. 138, and a very noticeable increase in the tension of the contacts will have been effected. Care must also be taken to see that the armature makes a right angle (90°) and that it is free on its pin.

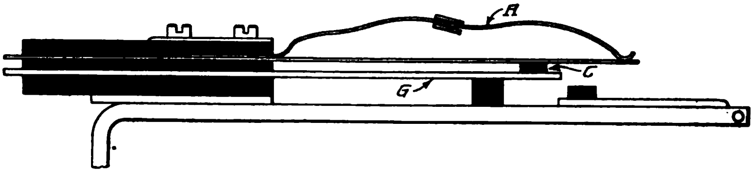


Fig. 137. Method of "Crowning" the Spring, Delco Ignition Relay

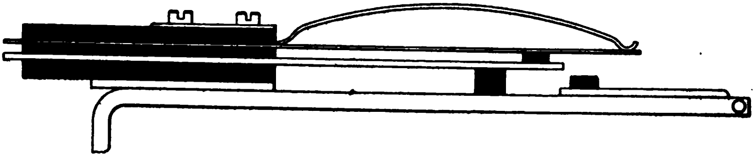


Fig. 138. How Springs Should Look when Properly "Crowned"

When properly adjusted, the ignition relay should take .6 ampere when furnishing a vibrating spark with the engine at rest, and the reading of a *dead beat* type of ammeter, similar to the Weston miniature-precision instruments, should be approximately .15 ampere when the ignition switch is thrown on.

TESTING, ADJUSTMENT, AND MAINTENANCE

Trouble Nearly Eliminated by Efficient Devices. With modern equipment, trouble from electrical sources has been decreased to an almost irreducible minimum and with a knowledge of the rudiments plus consistent observance of a few simple rules, these troubles can usually be remedied without calling in outside assistance. Causes of failure are the most important thing to remember as, with these in mind, it is far easier to trace the trouble logically than where the usual aimless hunt is undertaken on the chance of striking the cause. It must also be borne in mind that all causes of motor stoppage are not electrical. A dry gasoline tank, a plugged-up gasoline feed line or a choked carbureter, failure of a gasoline pressure-feed system, or a stopped-up air vent in a gravity-feed gasoline tank will have the same effect, though one or all of them have not infrequently been attributed to the ignition system.

Causes of Failure. Failures may be generally classed under three heads: short circuits or grounds; failure of current supply; and failure of ignition devices, such as contact breakers, distributors, vibrators, coils, spark plugs, wiring, connections, condensers, etc.

Short-Circuits. When a motor that has previously been running normally suddenly stops dead, the indication is almost invariably that of a short-circuit or ground. The difference between the two is that a short circuit takes place between two wires or other parts of the system, while a ground is the contact of a chafed wire or other exposed part with some portion of the metal foundation of the car, such as the frame or motor. The effect is the same in either case in that the current takes a shorter path and does not reach the spark plugs. Either may occur in the low- or high-tension wiring, i.e., between the contact breaker and the coil or the battery and the coil; or between the secondary side of the coil and distributor. Owing to the high voltage of the latter, grounding is more apt to result there either from a chafed wire or from a frayed end coming in contact with the motor or other metal. Failure from this cause can frequently be detected by sparking at the point of breakdown. An "open circuit" in one of the main feed cables, such as that connecting the magneto to the primary of the coil in a dual system, or the secondary of the coil to the distributor, or the battery cable in a battery system will naturally have the same effect. The cause is usually a loose connection; sometimes, though rarely, a broken wire. If the connection has not parted entirely, irregular firing will result.

Failure of Current Supply. Failure of current supply will usually result in erratic running as the current weakens until it reaches a point where it is no longer adequate and the motor stops. But the symptoms in this case are the same as in gradual failure of the fuel supply, either through a choked carbureter nozzle, partially obstructed feed line, stopped air vent, lack of pressure, or the emptying of the tank. The motor will run by fits and starts with irregular missing at different cylinders. Defection of the contact breaker or distributor may also manifest itself either by similar erratic operation or by sudden stopping.

Weak Magnets. When the engine fires regularly on the battery but will not do so on the magneto except above a certain speed, it indicates that the magnets are weak and need remagnetizing. Heat and vibration weaken the magnets, so that on some cars it is necessary to overhaul the magneto every five or six thousand miles, whereas, on others, the magnetism shows no appreciable falling off after two or three seasons' use. With a new or recently overhauled magneto it should be easy to start on the magneto by spinning (by hand), but this is not conclusive as some engines will never start on the magneto.

Testing. *Inspection of Wiring.* Examination of the wiring and other parts of the system will usually suffice to reveal short circuits or grounds, or by making emergency connection with extra wire, proper operation through the latter indicating a failure of the parts of the wiring system thus replaced. Extra wire should always be carried on the car for this purpose. With the dual type of ignition system so generally employed, see that the zinc-containing case or the protruding terminals of dry cells are not allowed to come into contact with the metal battery box as this will cause a ground that is difficult to locate. The best preventive is a small wood container to insulate these cells from contact with any metal. Water falling on the high-tension cables will cause serious leaks that will not show in the form of sparks. Above all, every part of the system must be kept dry; sufficient precautions are frequently omitted when washing the car.

Inspection of Current Supply. To make certain that erratic operation is not due to failing current supply, a small testing instrument, such as that shown in Fig. 139, should be carried on the car. This is the Hoyt multimeter, which gives an independent ampere and voltage reading by dials on both sides of the instrument. Either may be used separately or both simultaneously. For dry battery testing an instrument with a high reading ampere scale is necessary, that shown being for the current consumption of a battery-operated vibrator coil where economy is essential. Dry cells should test at least 10 to 12 amperes to give an efficient spark, though they will frequently operate on less. An ammeter should never be employed on a storage battery. For this the voltmeter affords the best test. Full instructions for the care of storage batteries are given in the article on "Electric Vehicles".

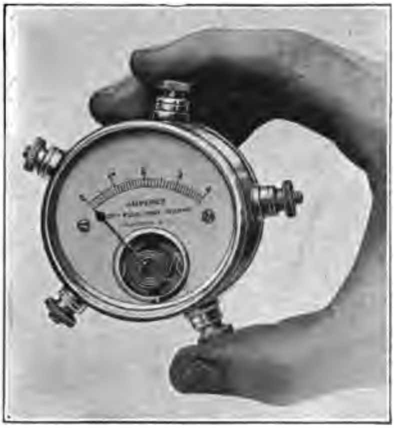


Fig. 139. Hoyt Testing Volt-Ammeter for Automobile Use

Solving Troubles. *Inspection of Contact Breaker.* Derangement of the contact breaker is almost invariably due to wear. In time the contact points will burn away unevenly, this being more rapid in older types not provided with a condenser. If not too far gone, straightening with a very fine file and adjustment will remedy this. Or they may wear down so far that the cam no longer separates them, thus preventing the secondary coil from coming into operation, as the circuit is not opened in the primary and no spark takes place at the plugs. Ample adjustment is provided to take care of this and with a little truing up of the points the trouble will be cured. These contacts will sometimes wear to a point at which the cam will still continue to open them when running at high speed, but fails to do so when the motor is cranked for starting (dual system). This provides the anomalous case of a motor running perfectly the day before and absolutely refusing to start when next cranked. It represents one of the obscure ailments mentioned, as every other part of the system will respond to the usual tests.

Remember Effect of Compression on Spark. The effect of compression on the spark must also be borne in mind, as an apparently efficient spark with the plug out of the cylinder is not equally effective when subjected to the compression. Partial failure of the current supply is the cause in this case, due to weak dry cells or an almost wholly discharged storage battery causing a drop in the voltage. Or it may result from spark plug points that have been burned away until the gap is too great, $\frac{1}{32}$ inch being the maximum distance recommended.

Leakage at Distributor. Leakage may occasionally occur at the distributor due to the use of an excessive amount of lubricating oil which picks up carbon dust, the latter being carried around by the revolving arm until it forms a path for the high-tension current.

Spark Plugs. A broken spark plug porcelain or an internal short circuit of the plug, neither of which may be evidenced externally, will cause missing at that cylinder.

Erratic firing and a very perceptible loss of power will result from the gaps of the spark plugs being too large. With the powerful current supplied by a storage battery or by the modern magneto this takes place by the burning away of the points of the electrodes in a comparatively short time, it being nothing unusual for the $\frac{1}{32}$-inch gap to increase to almost $\frac{1}{8}$ inch in a few weeks' running. This is particularly the case with the cheaper plugs which have iron-wire electrodes; they may be adjusted with the pliers, however, until there is no longer sufficient electrode left to adjust.

Loss of power will also be occasioned by a plug that is not tight in the cylinder or where the plug itself is not tight internally. Squirt a few drops of oil around the base of the plug on the cylinder and also on the porcelain of the plug. When the engine is running bubbles will form at these points: if the plug itself is at fault, a quarter-turn of the nut holding the porcelain in place will usually seat it on the gasket and overcome any leakage at that point; in case of leakage around the thread of the plug, a new asbestos gasket under it or a slight tightening of the plug itself where of the iron-pipe thread class will remedy the trouble. Cleaning at intervals with a stiff brush and gasoline will prevent short-circuiting through an accumulation of carbon on the porcelain and walls of the shell.

Sparking at Safety Gap. In all magnetos of the true high-tension type, the safety gap is incorporated in the magneto itself: in dual-ignition systems it is in the coil, as the latter must be protected from the battery current as well as from that of the magneto. Sparking at the safety gap is an indication that there is an opening in the circuit greater than the resistance of the secondary winding of the coil, and unless the spark bridged the safety gap, the insulation of the high-tension winding would be punctured. This opening may be a spark plug whose points are too far apart or a connection that has dropped off either at the plug or at the coil. Owing to its high voltage the current will jump any gap smaller than that of the safety gap with no perceptible difference in the firing, so that loose connections on the high-tension side seldom cause trouble until they actually separate. A piece of metal accidentally falling on it or an accumulation of any conducting material such as dirt or moisture will short-circuit the secondary of the coil through the safety gap and no current will reach the plugs. Frayed terminals in which one or more of the strands of the flexible wire protrude and touch adjacent objects are sometimes responsible for a similar result; the remedy is to wind with friction tape.

Breakdown of Magneto. On cars employing a true high-tension type of magneto, the battery system is entirely independent, as a rule, so that a fault in one never involves the other. Where failure of the magneto is not due to faulty operation of the interrupter, it may be inspected with the aid of the test lamp described in connection with starting and lighting systems. Trace the various circuits of the magneto in question; apply the points to the opposite sides of the condenser. The lamp should not light; if it does, the condenser has broken down and must be replaced. Test the primary and secondary windings of the magneto in the same way; the lamp should light in each case; if it does not, there is a break in that particular winding and a new armature will be required. In the case of the dual-type magneto there is only one winding on the armature, and many of the older makes (1910 or earlier) have no condenser. Many of these older magnetos in the cheaper grades are fitted with plain bearings and the wear of the latter may allow the armature to bind against the pole pieces, or lack of oil may cause the shaft to bind in its bearings.

When a magneto is taken apart for any reason it must always be assembled with the magnets in the same relative position as formerly, otherwise their polarity will be reversed and the magneto will be inoperative. The magnets must never be left off the machine, even temporarily, without placing a bar of iron or steel across their poles to serve as an armature or "keeper"; unless this is done, they will lose their magnetism rapidly. Remagnetizing the magnets of a machine that has become weakened through long use is a simple process and small electromagnets for this purpose are now to be had for garage use. They will operate, of course, only on direct current.

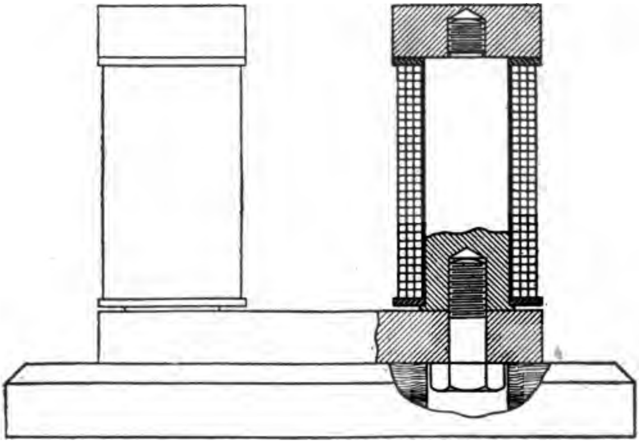


Fig. 140. Design for Magnet Recharger
Courtesy of "The Horseless Age"

Remagnetizing. As misfiring at low speeds may be due to causes other than weak magnets on the magneto, the strength of the latter should be tested before deciding that it is necessary to remagnetize them. With the engine running, unclip one of the spark plug leads and hold it close to the terminal. If the magneto is developing a powerful current, it will jump a gap of ½ inch or more; should it not produce a spark at least ¼ inch long it needs remagnetizing. In recharging the magnets their original polarity must be preserved, as otherwise it will be necessary to shift their locations in reassembling them. Accordingly, it is important that unlike poles of the permanent magnets and of the electromagnet be brought together; i.e., the north pole of the permanent magnet to the south pole of the recharging magnet and vice versa. To insure this, the current should be turned into the recharging magnet and the other magnet held freely a short distance from its poles. As unlike poles attract and like poles repel, the magnet will find its own proper position, if allowed to do so. If forcibly held against the poles of the recharging magnet regardless of polarity, the strength of the electromagnet is so much greater than that of the weakened permanent magnets that it will reverse their polarity.

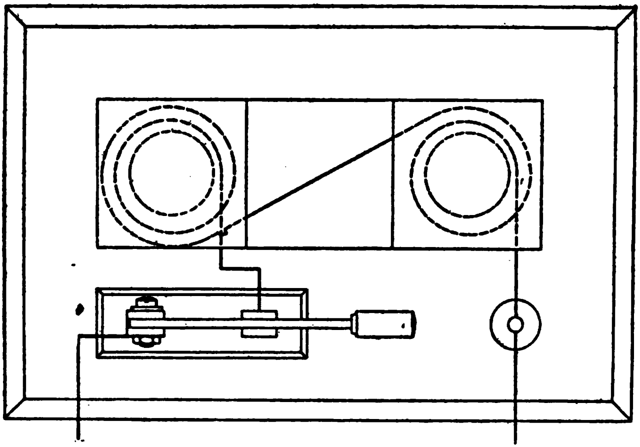


Fig. 141. Diagram of Connections of Magnet Recharger
Courtesy of "The Horseless Age"

In recharging, set the magnet on top of the charger after its polarity has been determined and rock the magnet back and forth on its pole edges a number of times; then lay it on its side with its poles away from you and, extending just beyond the far edges of the recharging magnet poles, apply a keeper to the magnet poles, switch off the current and withdraw the magnet sideways from the recharger. The keeper should remain in place until the magnets are reassembled on the magneto.

Magnet Recharger. Electromagnets designed for this purpose and built specially for garage use are now on the market, or one may be made with little trouble. The following design, Fig. 140, is from *The Horseless Age.* The cores of the magnet are made of soft bar steel 1 inch in diameter and 3 inches long. They are secured to a base measuring 5¼ by 1½ by ⅝ inches and are provided with pole pieces measuring 1¾ by 1¾ by ⅝ inches. All contacting surfaces should be absolutely flat and square so that there will be good metallic contact over the entire surfaces. Before the wire is wound on them, the magnets must be insulated. A spool may be formed by placing a fiber ring at each end of the magnet cores, and a better job may be made by turning down a 1⅛-inch bar, leaving a thin collar of the original diameter at one end. This will support the fiber ring at that end while the other rests against the pole piece. The core between the fiber rings is then insulated by wrapping with several layers of muslin which is given a coat of shellac in alcohol and allowed to dry.

The winding to be applied depends on the voltage to be used. For a 6-volt battery, wind on three layers of No. 12 double cotton-covered magnet wire; for a 110-volt circuit, eight layers of No. 22 double cotton-covered magnet wire. The ends or leads of the wire are then taped and the outer layers of the coils shellaced to make the exposed cotton insulation more enduring. Connect the coils together so that if the current flows through one right-handed, it flows through the other left-handed, when looked at from above, Fig. 141. Mount the completed magnet on a wooden base large enough to carry a single-pole switch and a binding post. The battery or lighting mains are connected to the binding post and the free terminal of the switch; the other terminal of the switch being connected to one end of the magnet coil and the other terminal of the latter to the binding post. Where designed for 110-volt current, it will be preferable to use a double-pole switch mounted on a porcelain base with two screw-plug fuses; 10-ampere fuse plugs being screwed into the sockets. The free ends of the coil are then connected directly to the terminals of the switch at the plugs and the source of current is connected to the other end of the switch. The windings specified will heat up quickly, when connected to current sources of the voltages given, so that the switch should never be left closed more than a few minutes at a time.

Where direct-current mains are accessible, the magnets may be recharged without dismounting them from the magneto. Being flexible and well insulated, lamp cord may be used and must be wound directly on the magnets. The bared ends of the cord should be twisted together so that the two wires form a single conductor. Wrap on about fifty turns and connect this winding to the main switch through a 10-ampere fuse. Particular care must be exercised to make the connections so that the magnets will not have their polarity reversed. A current of high value will flow through the winding during the brief time that it will take to blow the fuse. While this method obviates the necessity of taking the magneto apart, the latter involves so little labor that the use of the magnet recharger usually will be found preferable, particularly where there is any doubt as to the polarity.

Care of Ford Magneto. Dirt will sometimes accumulate under the collector brush or on the collector ring and reduce the current output. As a guide to the operation of the Ford magneto, the Hoyt magnetometer, Fig. 142, has been devised. The calibration of this is purely arbitrary, the letters representing Poor, Medium, Good, and Excellent. Probably end play in the bearings is the most frequent cause of poor operation of the Ford magneto. This is due to wear of the main crankshaft bearings which permits the magnets to rotate at a greater distance from the coils than originally intended. Taking up this play or replacing the bearings is naturally the remedy. Small particles of metal may sometimes lodge beneath the ribbon terminals of the coils, or the latter may become so thoroughly impregnated with metallic dust as to ground them, making them inoperative. Cleaning and renewal of the oil in the magneto housing will remedy this. To test the coils, four or six dry cells connected in series should be used. Attach one terminal of the battery to the collector brush or insulated plug at the top of the magneto and the other terminal to the connection where the last coil is grounded to the supporting plate. Then with a piece of soft iron touch the iron core of each coil to see it if is strongly magnetized. It should take some effort to pull the iron away. A coil that does not respond properly is probably grounded. Weak magnets are occasionally

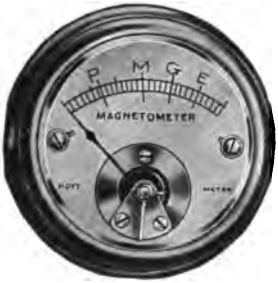


Fig. 142. Hoyt Magnetometer for Ford Cars

found to be the trouble, but this is comparatively rare, as well-made permanent magnets are usually good for years of service. When they are found, the best remedy is to replace the entire set, particularly as the cost is low.

SUMMARY OF IGNITION INSTRUCTIONS

Q. How many different systems of ignition are in use on the automobile today?

A. Generally speaking, only one, known as the high-tension system. The low-tension system used in earlier days has been obsolete for a number of years. The single classification, however, may be subdivided into several others which are known by their distinguishing features, the first being determined by the source of current supply, as magneto- and battery-ignition systems. These two classes may be divided further according to the type of magneto employed, such as the duplex, the dual, and the double-spark types. All battery systems are fundamentally the same, only differing in the type of circuit breaker and distributor employed, the mounting of the latter, i.e., whether direct driven from the engine or combined with the lighting generator, and in the type of controlling switches and auxiliary devices.

DIFFERENT SYSTEMS

Q. Why is the system generally used termed "high-tension" system?

A. Because the current must be passed through a step-up transformer or coil to impress upon it a sufficiently high voltage to cause it to jump the air gap in the spark plug.

Low-Tension System

Q. Is the old low-tension make-and-break system entirely obsolete?

A. Since about 1909, it has not been used on the automobile but is still generally employed on small two-cycle marine engines and on stationary engines.

Q. Why is it not suitable for automobile engines?

A. It will not work satisfactorily at high speeds since its time factor is limited by mechanical reasons, i.e., the inertia of the movable electrodes of the low-tension spark plugs, whereas, in the high-tension system, only electrical lag has to be compensated for. It requires a skilled mechanic to time the spark plugs properly and they will not stay in adjustment for very long.

Q. What is the chief attention it needs as employed on marine and stationary engines today?

A. Keeping the electrodes clean; the current burns a film of oxide on the contacts and this insulates them to an extent where the low-voltage current will not pass. The timing of the plugs also needs regular attention as the hammering action of their operation tends to throw them out of adjustment. Considerable current is required for the efficient operation of the low-tension plugs, so that where used with batteries as on the motor boat, the cells frequently become exhausted in a comparatively short time.

Q. How can the low-tension plugs be adjusted to give them the proper timing?

A. Turn the engine over slowly by hand and watch the action of the plug. Its contacts should come together when the piston is three-fourths of the way up on the compression stroke; they should snap apart to cause the spark, the advance lever being in the retarded position, when the piston is at upper dead center. Provision is usually made for increasing or decreasing the length of the rod that operates the plug. If the spark is occurring too late, causing a falling off in the power, shorten the rod sufficiently by the adjustment to give the timing suggested above and lock tightly; if too early, lengthen it just enough to overcome any hammering that this would cause.

Q. Why should the plug close the circuit so long before the piston reaches upper center?

A. To give the coil sufficient time to "build up", i.e., for its core to become "saturated", or thoroughly magnetized, as the efficiency of the spark produced depends upon this.

Q. How does the coil of a low-tension system act?

A. It is a single winding of coarse wire on a very heavy core of fine iron wires, i.e., a coil having a high self-inductance. When the circuit has been closed a sufficient length of time to permit this core to become saturated and is then suddenly broken, the current utilized to magnetize the core is redelivered to the coil and causes an arc at the plug as its contacts separate. The current producing this arc is of much greater volume and at considerably higher voltage than could be obtained by making and breaking the battery circuit without a coil in it.

Q. Does the coil ever need attention?

A. Only to see that its connections are clean and tight and that it is kept dry; owing to the solidity of its construction, failure of the coil itself is almost unknown. Test by holding one terminal of a three-cell or four-cell dry battery on one binding post and wiping the other with the wire from the other side of the battery circuit; a bright flash should result. If it does not, see if the wire has broken near one of the binding posts as this may result from vibration.

Q. Is this the only low-tension system used?

A. No. Several makes of magnetic plugs have been used in connection with low-tension systems. Each plug is a solenoid the plunger of which makes and breaks the contact electrically. No mechanism is necessary to operate the plug but a timer must be used in the circuit to close the latter slightly in advance of the time for the spark to occur. This timer is the same as that used in the primary circuit of high-tension systems employing vibrator coils, as on the Ford.

Q. What difficulty is usually encountered with magnetic plugs?

A. They seldom withstand the heat of the engine for any great length of time, so that the insulation fails. Apart from this the troubles encountered are the same as with any other system using movable contacts, i.e., dirt on the contact points, failure to make contact, broken connections, weak battery, etc.

High-Tension System

Q. Of what does a high-tension system consist?

A. The essential parts of a high-tension ignition system are: (1) a source of current, such as a dry battery, the storage battery of the lighting and starting system, the direct-current generator of the latter, or a magneto; (2) a step-up transformer or induction coil, the primary winding of which is in circuit with the source of current supply; (3) a contact breaker or interrupter to open this circuit periodically, i.e., once every other revolution for each cylinder of a four-cycle engine; (4) a distributor in circuit with the secondary winding of the coil and provided with as many contacts as there are cylinders; (5) a spark plug for each cylinder; (6) primary and secondary cables for the respective connections, and a controlling switch to open and close the supply circuit or to change from one supply circuit to another, where both a battery and a magneto are employed.

Q. How do these essentials vary in different systems?

A. Where a battery is depended upon for the current supply, the interrupter and the distributor are usually combined in an independent device which is driven from the camshaft of the engine.

In the case of a magneto, both the interrupter and the distributor are integral with it. This does not apply to the Ford magneto which has a separate low-tension timer and uses no distributor, as there is a vibrating coil for each cylinder.

In what are commonly known as modern battery systems, the timer and distributer may be either mounted separately, as first mentioned, or combined with the lighting generator.

CURRENT SUPPLY AND APPLICATION

Magnetos

Q. How many types of magnetos are there in general use?

A. Two general classes, the low-tension and the high-tension, and various special types, such as the dual, the double-spark, the duplex, and the inductor magnetos.

Q. What is the difference between low-tension and the high-tension magnetos?

A. The low-tension magneto has only a single winding on its armature the current being generated at low voltage and transformed by passing through an independent coil, whereas the high-tension magneto generates the current in one winding and steps it up through another, both on the same armature.

Q. What is a dual magneto and why is it so called?

A. It is a low-tension type, the interrupter and distributor of which are also employed in connection with a battery for starting. It is so called because these essentials are common to both the magneto and the battery sides of the system.

Q. What is a double-spark magneto?

A. One provided with two distributors designed to produce two sparks simultaneously at two different plugs in the same cylinder.

Q. What is a duplex magneto?

A. One designed to permit of passing the battery current through the armature of the magneto to facilitate starting, the magneto and battery both acting together to produce the spark at low speeds. To accomplish this a commutator is mounted on the armature shaft and the battery connected to it, the magneto being of the high-tension type. This commutator causes the battery current to alternate in direction with that produced by the magneto so that it is said to be "in phase" with the latter.

Q. What is an inductor magneto and how does it differ?

A. An inductor is employed instead of an armature, the windings being stationary. The inductor is simply a revolving piece of metal which alternately opens and closes the magnetic circuit. In the K-W inductor magneto this winding is of copper ribbon and is placed between the poles of the inductor; in the Dixie magneto it is a conventional induction coil placed in the hollow of the magnets above the inductor.

Q. Why can a magneto not be run in either direction equally well?

A. Owing to the contour of the cam which serves to open the contacts of the interrupter. This must be designed to operate the magneto either as a "right-hand" or a "left-hand" machine.

Q. How is a magneto timed?

A. Disconnect its drive from the engine. Turn engine over by hand until the piston of cylinder No. 1 is exactly at the upper dead center on the firing stroke. Turn the armature shaft of the magneto to a point where the contacts of the interrupter are just beginning to open; the brush of the distributor which is then making contact with the distributor segment should be connected to the spark plug of cylinder No. 1. The next brush should be connected to cylinder No. 2 or No. 3, according to whether the firing order is 1- 2- 4- 3 or 1- 3- 4- 2. The armature of the magneto should be coupled to its driving shaft in the position as determined for the first cylinder.

Q. If after timing a magneto in this manner, it is found that the spark-timing lever does not give sufficient advance or retard, what should be done?

A. Remove the cover from the distributor housing of the magneto, the piston of cylinder No. 1 being at upper dead center of firing stroke and the interrupter contacts just about to open as directed for timing. Note the relative position of the segment and the distributor brush which should be making contact with it. If the segment has already passed the brush, the spark-timing lever being at the maximum advance position, remove the distributor gear from its shaft and from engagement with the pinion on the armature shaft. Move it back one tooth (against the direction of its rotation which is the opposite of that of the armature pinion) and remesh with pinion. If this does not bring it into contact with the brush, move back another tooth. Should the distributor segment not have reached the brush when in the position as given above, move the distributor gear forward, or in the direction of its rotation, one or two teeth, and remesh.

Q. How can the various types of magnetos be identified, as installed on car?

A. The two types in most general use may be distinguished at once by their external connections. The so-called dual type can be identified by its separate coil, or transformer, mounted on the face, or the front, of the dash, under the hood, and the connecting cables from the magneto to this coil. One of these connections is for the primary of the coil, and the other is for the secondary; the other ends of both coils are joined together and connected to a common ground wire, so that the coil has only three connections. The true high-tension type can at once be recognized by the fact that its only external wires are those connecting the distributor plate of the magneto directly with the spark plugs.

Q. Of these various types, which are most commonly used?

A. The dual type will be found on most low-priced cars (except the Ford), and the straight high-tension type on higher priced cars not using battery ignition.

Q. In searching for faults, is it easier to locate trouble in one type than in the other, and is the procedure different in each case?

A. Owing to its having but a single winding on its armature, and to the fact that all of its connections are external, the dual low-tension magneto is the simpler of the two; but the exposed location of its connections makes them more subject to default than those of the high-tension magneto. The procedure differs in that failure to operate, in the case of a dual magneto, may be caused by injury to, or the breaking of, some of these external connections; whereas, with the high-tension type, the cables are so short and so direct that the fault is likely to lie in the magneto itself.

Q. Where would be the most likely places to look for the cause of failure of a dual magneto to operate?

A. In about the order of their liability to occur, these would be as follows: broken or faulty connection at one of the coil terminals; primary or secondary cable, connecting magneto with coil, grounded through chafing or from being soaked with oil and water; ground between the dry cells and the metal battery box (this last is a not infrequent ground and is very annoying to locate, as it will occur one moment and disappear the next, owing to the vibration breaking the contact); dirt, oil, or excessive wear at the primary collector brush, and similar conditions at the brush which conveys the high-tension current from the coil to the distributor; failure of the coil through breakdown; failure of the condenser, causing the interrupter points to burn away rapidly; a break in the armature winding. All of these last are rare causes of trouble

Q. How are these faults best remedied?

A. Poor connections at the coil termimals can be overcome by baring about an inch and a half of the cable of insulation, twisting a ¼-inch loop in the end, and, after cleaning and wetting the braided end with soldering flux, dipping the loop into molten solder. The terminal nuts can be screwed down hard on these loops without opening or injuring the stranded wires, and they will make solid and permanent terminals. Where cables have become so oil soaked that the integrity of their insulation is suspected, they should be replaced, and the new wires properly supported. If either of the brushes is at fault, due to excess of oil and dirt, clean with gasoline, and true up the ends square with a fine file. Should the brushes have worn unevenly, or, in the case of the primary brush, taken on a hard, glazed surface, treatment with the fine file will remedy the trouble. When they have worn down to a point where the spring no longer holds them in good contact, new brushes and springs (attached) should be inserted.

Q. When examination shows no fault at any of these points, how can the coil be tested?

A. Disconnect the coil from the magneto, and connect to the battery terminal one wire from a spare battery of four dry cells or, if more convenient, to an ignition storage battery. Fasten the ground connection from the coil to some handy metal part of the chassis; lay the secondary cable from the coil on the chassis so that its bared end is not more than ¼ inch from the metal of the motor, or chassis. Then connect another length of wire to the opposite terminal of the testing battery. (The dry cells should be in series.) Scrape the end of this wire clean, and touch it rapidly to some part of the motor. A spark should occur every time it is touched, showing that the primary winding of the coil is uninjured, and, if the secondary is likewise uninjured, a spark should jump between the bared end of the secondary cable and the adjacent metal, every time the circuit is closed with the testing wire. The occurrence of these two sparks show the coil to be in proper working condition. If the spark occurs at the testing wire, but no high-tension spark takes place at the end of the secondary cable, it indicates that the secondary winding of the coil has broken down. Should the spark, taking place every time the testing wire is touched to a part of the motor, be very bright and hot, it is quite likely that the condenser has become punctured. Unless the failure of the secondary is due to a broken connection between the fine wire of the winding and the terminal, it must be sent to the maker for repairs. This is the case also when the condenser has been punctured. The magneto will continue to work with the condenser short-circuited, but this will cause a rapid burning away of the expensive platinum contact points of the interrupter.

Q. How is the magneto armature winding tested for a break?

A. Employ the test battery already mentioned. Touch one wire to the armature shaft, and the other to the collector end which is insulated from the shaft. A spark should result if the winding is intact. Failure to obtain a spark would indicate a break in the winding, and the armature should be returned to the maker for repairs. In making tests with a battery in this manner, always make sure that the connections from the battery have not pulled loose nor become broken, before finally accepting the lack of a spark, at the point where it should occur as conclusive evidence of a fault in the part being tested. Otherwise, a failure of the testing apparatus itself may be put down as a fault in the part being tested.

Q. Is a spark the best indication obtainable in making such tests?

A. With a fresh battery of dry cells, the self-induction of the coils tested, such as the winding of the armature or the primary of the coil, will give a bright spark that cannot be mistaken; but, if an audible indication be desired, the battery may be placed in a box and a common electric door bell, or buzzer, mounted on the box. The bell, or buzzer, must be connected in series with the testing wires, so that, when the circuit is completed, the current passes through it. Then the success of the test will be evidenced by the sounding of the bell, or buzzer, as long as the circuit is closed. In the case of the secondary winding of the coil, the spark is all that is necessary. Should a more visible signal be desired, the lamp-testing set, described in connection with trouble hunting on the starting and lighting system, may be employed. In this case, the test battery is dispensed with and the 110-volt lighting circuit used, but a 10-ampere fuse-block and fuses should be inserted in the testing circuit to guard against accidental short-circuits in handling the testing apparatus.

Q. As secondary cable is expensive, and the owner does not usually want it replaced unless absolutely necessary, how can it be tested for faults?

A. Connect the test battery to the coil, as previously described, but, instead of relying upon breaking the circuit by hand, insert a buzzer, or bell, in series, between the battery and the primary of the coil. This will give a vibrating contact, and will keep the coil working continuously. Connect the piece of cable to be tested to the secondary of the coil and support it well, clear of the ground, such as the motor or chassis. Take another piece of secondary cable and connect one end of it to the ground. Bare the other end, and pass this along the entire length of the cable being tested, very close to, or actually touching, the insulation of the cable under test. If there are any weak spots in the insulation, a spark will jump through it to the testing wire. In case a vibrating coil is at hand for making this test, it will not be necessary to insert the buzzer as mentioned.

Q. What is likely to result when there are weak spots in the insulation of the secondary cables?

A. The high-tension current will escape through them to the ground, because of the nearness or actual contact of the secondary cable with the motor cylinders or other metal parts. This leakage will be neither visible nor audible, unless the insulation is very bad, and the failure to fire will usually be attributed to the spark plug instead.

Q. **Should primary cables be tested in the same manner.**

A. It is not necessary; as, unless the insulation is actually worn off, there will be no escape of current, owing to its low voltage. Where solid instead of flexible primary wire is employed, as on some old cars, or where the owner has made replacements, a test for a break in the wire itself under the insulation may be made with the aid of the battery and buzzer alone.

Q. **Are the causes of failure similar in a true high-tension magneto?**

A. No. As the primary-generating winding and the secondary, or high-tension winding, are both on the armature of the magneto itself, and all connections, except the high-tension leads from the distributor to the spark plugs, are made internally, there are no outside cables, terminals, or coils to default. Unless the repair man has become proficient in testing electrical apparatus and has familiarized himself with the construction of the high-tension type, he will find it preferable to refer to the manufacturer any cases of trouble in this class of apparatus. In fact, the maker usually absolves himself from any responsibility in case a magneto of this type has been taken apart. Even where the repair man is capable of dismantling and testing this type of magneto, its repair would ordinarily be beyond his facilities, so that it is better to refer it to the maker at once.

Q. **Are there any faults, peculiar to the "duplex" or to the "double-spark" types of magnetos, which are not encountered in the others?**

A. In the case of the duplex type, there may be a failure to work of the battery connections or of the battery commutator on the armature shaft, i.e., the commutator which throws the battery current into phase with the armature current of the magneto when starting. Since the advent of the self-starter, this type of magneto has had no particular advantage to recommend it, and will be found only on older cars. As the only difference between the double-spark and the usual magneto is a duplication of the distributor to give two sparks in the cylinder instead of one, its treatment is the same.

There are simply two distributors to maintain instead of one. This type is also of limited application and will be found only on comparatively few cars of several years back.

Q. Why is it important that the magneto be accurately timed?

A. Unless the spark occurs at exactly the right moment, the motor will not operate efficiently. If it occurs too soon, the explosion will tend to retard the piston; if too late most of the power that would have been derived from the compression will be lost. As the lag, i.e., the time intervening between the moment the contact points are opened at the interrupter and the occurrence of the spark at the plug, is negligible in the magneto, it must be more accurately timed than the old battery and vibrator-coil system.

Q. Does the magneto ever fail to operate through lack of oil, and what attention should be given to its lubrication?

A. Prior to 1910, when some of the lower-priced magnetos were made with plain bearings, this naturally occurred, but, with the adoption of high-grade annular ball bearings for the magneto shaft, it is practically unknown. However, even the high-grade ball bearing will not operate without lubrication. If it runs dry, the balls are apt to rust and ruin the bearing. Most of these bearings are packed with vaseline, or similar light grease, when the machine is assembled and require no attention during the life of the average car. Where this has not been done, as on some of the older machines, a few drops of fine sewing-machine oil once a year will suffice. The pivot and roller of the contact-breaker arm also should be oiled once or twice a year with one drop of oil to each, using a toothpick.

Q. When taking a magneto apart, as where it is necessary to remagnetize the fields, why is it of the greatest importance to reassemble them in the same way?

A. Unless this is done, the polarity of the fields will be reversed and the machine will not generate properly. The maker usually identifies the polarity of the fields by marking the magnets so that it is easy to reassemble them in the proper manner. See the illustration of the Eisemann magneto, Fig 103.

Q. When remagnetizing the field magnets of a magneto, why is it important that their polarity should not be changed in the process?

A. The effect would be exactly the same as if the remagnetizing were carried out properly, so far as their polarity were concerned, and then the magnets were put back the wrong way. The machine would not generate. For example, the marking on the side of the Eisemann magneto indicates the north pole of its fields. If in remagnetizing, this side of the field is made the south pole, and it is then correctly assembled, it will be evident that the polarity of the entire field has been reversed.

Q. In the case of the dual magneto, how can trouble, caused by the grounding of the dry cells against the metal battery box, be overcome?

A. By making a tight-fitting wooden box to hold the battery, this wooden box fitting inside the metal one.

Q. Does the care required by an inductor type of magneto vary from that necessary for other types?

A. No. So far as its outside connections go, it is the same. That is, in a dual type installation, using an external coil, or transformer, the causes of trouble and their remedies will be the same as in any dual system, as already given; and this also applies to the high-tension dual type.

Q. In the order of their occurrence, what are the commoner causes of failure of the magneto, due to wear of its parts?

A. In practically every case of failure of the magneto that is not otherwise apparent at a glance, an inspection should always be made of the contact points in the breaker box. Unless they open properly when the cam strikes the lifter, no current reaches the outside circuit and the coil is not energized. Next, inspect the contact of the collector brush; see that it is clean; that it is making good contact over its entire surface; and that its spring is holding it firmly in place. After this, inspect the distributor.

Q. How often should the contact points in the breaker box require attention?

A. This will depend upon the type of magneto, and when it was made. On some of the earlier types, prior to 1909, no condensers were used on many of the lower-priced magnetos, and the points required attention every 3,000 or 4,000 miles. Others will run two or three times this distance without requiring attention. If, when the points have been found in poor condition, they have not been properly trued up and adjusted, they are apt to require attention again much sooner, as any irregularities in their contact faces will cause them to burn away much more rapidly.

Q. As the platinum contacts of the magneto breaker box are expensive, how far down can they be allowed to wear before it is necessary to replace them?

A. This will depend upon the amount of adjustment provided. As long as there is sufficient platinum left to provide a true surface on each contact point, it will not be necessary to replace them if they can be adjusted so that the cam opens and closes them properly.

Q. Since the magneto-armature circuit is normally closed upon itself and only opens when a spark is required at one of the plugs, how is the magneto ignition shut off?

A. By short-circuiting the armature around the contact points. Instead of opening the entire ignition circuit, as in the case of a battery where it is necessary to save current, the generating part of the circuit is closed. This is true of all high-tension magnetos.

Q. When the contact points of the interrupter of the magneto fail to separate, what is the result?

A. The armature remains short-circuited upon itself throughout the revolution, and no current reaches the outer circuit, so that the engine will not fire on the magneto at all.

Q. What is the result when the contacts open but the gap is not wide enough?

A. Erratic missing, probably at all speeds, but more pronounced when the engine is running slowly. The increased kick given the movable contact arm by the cam, when the engine is running at a higher speed will cause it to fire more regularly.

Q. What happens when contact points are separated too far?

A. The missing is likely to be more noticeable at high speeds than at low speeds; as, when turning very fast, the looseness of the movable contact arm may prevent it from closing the circuit again in time for the next cylinder to fire.

Q. What is the proper distance for the setting of the contact points of the magneto interrupter, or breaker box?

A. Approximately $\frac{1}{64}$ inch, or the equivalent of an ordinary sheet of paper. When the points are properly adjusted, it should be possible to insert the paper between them and move it around without binding.

Q. How are the contact points usually adjusted?

A. Practically every magneto manufacturer now supplies an adjustment gage, which serves also as a screwdriver or small spanner, according to the construction of the interrupter. The thickness of the metal represents the distance that the contacts should open. In all except the old types produced several years ago, the interrupter may be removed without the use of any tools, and the adjustment made without the necessity of removing the magneto from its bedplate. The following instructions cover the Eisemann dual type in this respect, and are typical: "Insert from behind through the hole in the plate carrying the make-and-break mechanism, the metal adjuster which we supply with every magneto: by means of a flat wrench hold the nut on platinum screw (contact) and turn the platinum screw upward or downward until there is a gap of $\frac{1}{64}$ inch between the contacts, i.e., a piece of paper must pass between them without getting jammed", Fig. 143.

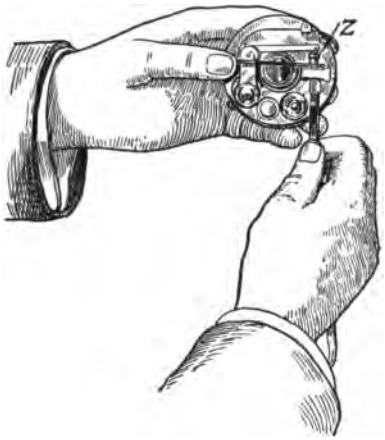


Fig. 143. Method of Adjusting Magneto Contact Points

Q. How often should the magnets of a magneto need remagnetizing?

A. No definite time nor average can be given for this. In some cases, the makers state specifically that the magnets will never need remagnetizing during the entire life of the machine, unless they are taken off and allowed to stand without a "keeper", i.e., a piece of soft iron placed across the pole pieces, the magnets themselves being placed in their usual relation as when on the machine. In others, it has been nothing unusual to require this once a year, or after 6,000 to 10,000 miles running.

Q. How can it be determined definitely whether the magnets actually need remagnetizing or not?

A. Many cases of weak or faulty ignition are attributed to loss of strength in the magnets, when they are actually due to some-

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thing else. Before deciding that the magnets themselves are at fault, every part of the system should be gone over thoroughly. See that the contact points are clean and true, and that they are properly adjusted; that the low-tension collecting brush, or contact, is clean and is making good contact; also, that the distributor is clean. Inspect all terminals and connections. Test the condenser. Disconnect one of the spark-plug leads, keep it away from any metal part of the chassis and, with the engine running, note whether a spark occurs at the safety gap. In a high-tension magneto, this gap is ually located in the hollow of the magnets back of the distributor; in a low-tension type, having a separate coil, it is usually on the coil. Take the spark-plug lead which has been detached (engine running) and approach its metal terminal gradually to the spark-plug end, or to some metal part of the engine, noting the maximum distance that the spark will bridge. If this is one-quarter inch or more, the magnets are not at fault.

Q. When there is no question but that the magnets are the cause of faulty ignition, how can the magnets be remagnetized?

A. With the aid of a small electromagnet, as described in the chapter on this subject. Care must be taken to see that the polarity of the magnets is not reversed in the process, as this will render the magneto altogether inoperative.

Q. How is the ground connection made in a magneto?

A. One side of the winding of the armature in a low-tension type, and of both windings, i.e., the primary and secondary are grounded by being electrically connected directly to the core of the armature itself, in the high-tension type. The fastening of the magneto in its bedplate on the engine, completes this ground connection.

Q. Is it ever advisable to insert paper liners, or liners of any material, between the magneto and its bedplate?

A. If on an old car, it is necessary to resort to liners or shims to correct the alignment of the magneto with its driving shaft, nothing but thin sheets of brass or iron should ever be employed, as the use of any insulating material for this purpose would break the ground connection and prevent the magneto from functioning properly. But even on old cars, where the lack of alignment of the magneto with its shaft is such as to be plainly perceptible to the unaided eye, the Oldham coupling usually employed on the driving shaft, allows sufficient play to compensate for this. Any lack of alignment is more likely to be due to carelessness in replacing the magneto after it has been removed from the engine for attention, than to any fault in the placing of the bedplate and driving shaft.

Q. What will be the result of the magneto being lined up incorrectly?

A. The universal coupling is apt to wear badly, and the side pressure, which the lack of alignment causes, may not be taken care of entirely by the coupling, so that the pressure has to be taken in part by the magneto shaft and its bearing. This will result in undue wear of the bearing and, in time, may permit the armature core of the magneto to strike the pole pieces, or sides of the tunnel, so that it will jam. On many of the higher-priced cars, a flexible coupling, consisting of leather discs, is employed for the magneto drive.

Q. Which is more likely to occur, separation of the points by too great a distance or their coming together so that they do not open?

A. The result of wear will usually be to increase the distance between the points, but the writer has experienced the opposite on an old car where the cam apparently wore down faster than the points and prevented their opening. This was probably due to improper hardening of the cam itself or to the fact that the roller was harder than the cam. Many of the later models do not employ a roller in the movable contact arm, the cam striking directly against a projection on the arm itself (see Eisemann interrupter, Fig. 143). An example of the roller type, is the K-W interrupter, Fig 69.

Q. Is it possible for the adjustment of the contact points to wear to such a degree that the magneto will fire the engine at high speeds, but not at all at low speeds?

A. Instances of this nature on old magnetos have proved a puzzling cause of ignition failure. The extra kick of the cam at high speeds would separate the points, whereas at low speeds they remained together.

Q. Inspection having shown other parts of the ignition system to be in good order, how can it be determined whether the magneto itself is at fault?

A. Run the engine on the battery, and switch from battery to magneto while the engine is running at a good speed. If the magneto is not operating properly, the difference in running will be perceptible immediately; in case the contact points are not opening, the explosions will cease at once upon throwing the switch to "magneto".

Q. What is meant by "ignition timing"?

A. A four-cycle motor is so-called because there are four parts to each cycle: viz, suction, compression, firing, exhaust. It is evident that ignition is necessary only at one part of the cycle and that the spark must occur at a certain time with relation to the carrying out of that part of the cycle. Determining the point at which the spark is to occur in that part of the cycle is usually referred to as the "timing of the spark", or as the "ignition timing".

Q. Is it necessary that this be carried out with precision?

A. In the high-speed automobile motors of the present day, it must be extremely accurate with relation to the movement of the piston and must be exceedingly rapid in action; otherwise, the efficiency of the motor would suffer greatly. In the slower-running motors with fewer cylinders, of several years ago, neither of these factors was of such great importance; but the present-day high-speed multi-cylinder motors could never be operated satisfactorily on ignition apparatus of the type familiar on 1910 models, for example.

Q. Why would a variation or a lack of precision affect the running of the motor?

A. Speeds are now so high that the time factor is reduced to exceedingly small fractions of seconds. For example, take a high-speed four. It turns at 2500 r.p.m.: as there are two explosions per revolution in a four-cylinder motor, this would mean 5000 sparks per minute, or one spark every .012 second. This is cutting time pretty fine, but in a modern twelve-cylinder motor, it is finer still. Say the twelve runs at 3000 r.p.m.: in a twelve there would be six explosions per revolution, requiring 18,000 sparks per minute, or one for every .0033 second—thirty-three ten-thousandths of a second—an incredibly brief space of time in which to carry out a combined mechanical and electrical function.

Q. How is this extreme accuracy obtained?

A. By the use of precision machine work in the distributor, approaching that of a fine watch, and a great amount of "advance" to compensate for any lag in either the mechanical or electrical functioning of the apparatus.

Q. What is meant by "lag", and what is the difference between mechanical and electrical "lag"?

A. As the term implies, lag is delay: in other words, it is the time elapsing between the moment a part begins to move and the actual moment at which it moves and makes contact or carries out the function for which it is designed. Mechanical lag is due entirely to the time necessary to overcome the inertia either of a part that is stationary or of one that is moving in another direction and whose direction must be reversed. Electrical lag, on the other hand, is the time elapsing between the moment that current is switched into a piece of electrical apparatus and the moment that the apparatus actually operates. This will appear strange at first sight in view of the universal belief that anything electrical operates so swiftly that it is next to impossible to measure the time required. This is true when nothing more than the passing of a current of electricity from one point to another is concerned, but when actual work must be performed by the current, the time required is not only measurable but it may be so perceptible as to have a decided effect upon such extremely rapid functioning as that mentioned. For example, when the work to be performed by the current consists of magnetizing the core of a coil, as is necessary in automobile ignition, the time element is quite perceptible, as may be noted by referring to the oscillograph of the spark produced by an induction coil, Fig. 95. A coil having the characteristics shown by this oscillograph would be worthless on a modern high-speed motor.

Q. How is this lag compensated for?

A. By advancing the moment that contact is made outside of the cylinder to an extent that will insure the occurrence of the spark in the cylinder at the proper moment. In other words, the current is started on its way sooner with relation to the movement of the piston. This is generally referred to as "advancing the spark".

Q. What is the proper point, in the travel of the piston on the compression stroke, for the ignition spark to occur?

A. Exactly at the upper dead center just before the piston starts downward again. The compression is then at its maximum, and firing the charge exactly at that moment results in the production of the greatest amount of power. The compression falls off very rapidly the moment the piston starts down on the power stroke, so that in a high-speed motor, the loss of even a very minute fraction of a second causes a considerable loss of energy.

Q. What will happen if it occurs too soon?

A. This will depend largely upon the type of motor and upon how much in advance of the proper time it actually occurs. In a slow-speed type running well below its normal r.p.m. rate, as where a motor with a normal speed of 1000 r.p.m. is slowed down to 600 r.p.m., owing to climbing a hill, advancing the spark to its maximum will cause hammering or pounding in the cylinders, indicating that the explosion is taking place before the piston reaches upper dead center and, consequently, that most of its energy is being expended against the rising piston, instead of helping thrust it downward as it should. When running at its normal rate, the piston speed of such a motor would be sufficient for the piston to have reached upper dead center before the burning gases had time to expand, so that their entire output of energy would be expended in producing power. In high-speed multi-cylinder motors with their diminutive cylinders and light moving parts, the piston speed is so great that even the maximum advance in the ignition timing would have no effect, even as the lowest speed of which the motor is capable.

Q. What is the result when the spark occurs too late?

A. The piston has already started on its downward stroke; the point of maximum compression has been passed, so that the full benefit of the compression is lost, and with it, a large part of the energy that would otherwise have been utilized.

Q. Has running with a late spark any other effect on the motor?

A. Yes. The gas in the combustion chamber is ignited so late that it continues to burn after the exhaust valve is opened. As the heat units it contains are not utilized as power, they are retained longer in the cylinder in the form of heat; the water jackets are compelled to absorb 50 per cent more of the heat than they should; and the whole motor is said to "run hot" or to "overheat". The late combustion of the gases does not permit of sufficient time for the normal amount of heat to escape by way of the exhaust, so that there is still burning gas in the combustion chamber when the exhaust valve closes.

Q. What other term is used in referring to a late spark?

A. Retarded ignition, or a retarded spark, meaning one that occurs later in the firing part of the cycle, i.e., later with relation to the travel of the piston itself. An *early spark*, or advanced spark, is set to occur or rather *start* to take place well before the piston has reached upper dead center on the compression stroke. The time of ignition is always based on its relation to the position of the piston, though frequently referred to in terms of degrees on the periphery of the flywheel. This is done for greater convenience in setting the ignition, as the timing of the valves is always marked on the rim of the flywheel.

Q. Why is it necessary to have the ignition occur later at one time than at another?

A. To permit of starting the motor, especially by hand. The time of ignition is advanced to compensate for the extremely rapid travel of the piston, and is designed to cause the spark to take place just as the piston reaches upper dead center on the compression stroke. In high-speed motors this advance amounts to as much as 1 inch of the stroke. It will, accordingly, be evident that if an attempt be made to start the motor with the spark advanced, ignition will take place before the piston reaches upper dead center and the motor will kick back.

Q. How much allowance is usually made for retarding the time of ignition?

A. In the ordinary type of motor in which the speed does not exceed 1500 to 1800 r.p.m., it is customary to have the latest timing allowed coincide with the upper dead center position of the piston. In some cases, the spark may be retarded to take place after the piston has traveled a short distance down on the firing stroke, or about 5 degrees to 7 degrees on the rim of the flywheel. In the majority of cases, however, "extreme retard" is at the upper dead center of the piston.

Q. How is the time of ignition, or "spark", advanced and retarded?

A. The timer, in the case of a system using vibrator coils, and the distributor, in all systems using one vibratorless coil, consists of two parts. In the case of the timer, the four contacts for a four-cylinder motor are set into the inner periphery of a circular casing and a single revolving contact, mounted on the camshaft, passes over them consecutively, sending the current through the primary winding of each of the induction coils in rotation. These coils are connected to the spark plugs of the different cylinders in the proper firing order. While this outer casing of the timer is normally stationary, it may be moved part of a revolution with relation to the position of the revolving contact. For example, if the moving member in its revolution were within 20 degrees of touching the contact corresponding to coil and cylinder No. 1, and then the casing were revolved 20 degrees in the same direction as that in which the contact is moving, it will be evident that the meeting, or contact, of the two will take place that much later, and the occurrence of the spark in the cylinder will be correspondingly delayed. If, instead of being moved away from the revolving contact, the housing is revolved against the direction of rotation of the contact, the two will come together that much sooner and the spark will be advanced, or occur earlier. This housing of the timer is connected by means of linkage with the spark lever under the steering wheel.

In the case of the distributor, the principle is exactly the same, except that the current is sent in turn by each one of the contacts, through the same induction coil, instead of having a coil for each cylinder. The method of accomplishing this result is also varied: in many magnetos the distributor consists of a revolving block carrying a single contact, while a carbon brush for each cylinder bears against it. In most of the battery-system distributors, the arrangement is very similar to a timer, but the construction and insulation are naturally carried out in very much better fashion.

Q. What is meant by an advance of 30 degrees for the ignition?

A. That the difference between the point of extreme retard, usually upper dead center of the piston, and that of maximum advance or earliest ignition for high speed, represents 30 degrees on the flywheel. Just what this corresponds to in inches on the flywheel naturally depends entirely upon the diameter of the flywheel.

Q. What is meant by the magneto setting point?

A. This is a line inscribed on the flywheel in the same manner as the usual marks for the valve timing of the motor. There is a corresponding dead line, or pointer, on the crankcase, with which these lines on the flywheel are registered to check the valve timing and the setting of the magneto. When the magneto-setting lines on the flywheel is directly opposite the dead line, or pointer, on the crankcase, the piston of cylinder No. 1 should be at upper dead center exactly on the compression stroke, i.e., on the previous down stroke, it has drawn in a fresh charge, and when the piston again reaches upper dead center it has completed compressing this charge, so that the cylinder is then ready to fire. With the piston of this cylinder at the position in question, the contact points in the breaker box of the magneto should be just opening.

Q. How is the ignition timing advanced or retarded on a magneto?

A. The magneto breaker box may be moved part of a revolution, with relation to the contact points, in exactly the same manner as previously described for a timer or distributor. This alters the relation of the cam which opens the contact points to the latter so that their separation takes place earlier or later, in accordance with the direction the breaker box is rotated.

Q. Why is it that a motor may be cranked by hand with the spark lever in the fully advanced position when starting on the magneto, and why can this not be done safely with a battery?

A. There is less actual advance in the time of ignition, as supplied by the magneto, represented by the movement of the spark lever. That is, moving the spark-advance lever to its maximum does not cause so much advance in the actual timing of the ignition when connected to the magneto for starting, as it does when connected to the battery. The speed of the magneto itself is responsible for a considerable advance in firing time when the motor is running, whereas the battery ignition has a fixed speed of operation, regardless of whether the motor is being turned over by hand or is being run full speed. Moreover, as the usual magneto setting point is upper dead center, the spark does not actually occur until slightly later, when the motor is being cranked slowly, so that, while the spark lever may be in the advanced position, the actual occurrence of the spark is not perceptibly earlier than it would be with the lever fully retarded. This makes it possible to crank the motor with the lever fully advanced on the magneto, without any danger of a backfire. This is not true to the same extent with the Ford magneto as with other types, owing to the great number of pole pieces and armature coils that it carries. With a battery, however, the occurrence of the spark is just as rapid at low speeds as at high, so that attempting to start on the battery with the lever fully advanced will invariably result in a vicious back kick; the whole force of the explosion is exerted against the rising piston. As there is a greater amount of lag in the ordinary battery system than there is with the magneto the movement of the spark lever represents more actual advance, as this is necessary to provide for the time lost in the operation of the system. This, however, applies only to old battery systems, such as the dry cells used in connection with the magneto in a dual systems and not so much so to the so-called modern battery-ignition systems which are practically as rapid as the magneto.

Q. What is meant by fixed ignition?

A. The time of ignition is not variable by means of a spark-advance lever. Only a magneto is employed (true high-tension type) for ignition and it is set to fire at the maximum advance at all times when running. Provision is usually made for retarding the time of ignition to allow for hand starting, though this is not always the case, as it is not absolutely necessary (see answer to previous question). Otherwise, the ignition is always advanced to the maximum and there is no lever on the steering wheel for varying it. This type of ignition system has been very generally employed abroad and, more particularly in France, on commercial vehicles, such as cabs, but has never found any favor here. It has not been used in this country, except on a very few makes of cars, and then only for the models of one or two seasons, the latest being about 1912.

Q. What is meant by automatically advanced ignition, and how is this accomplished?

A. Instead of relying upon a manually operated spark lever under the steering wheel, a centrifugally operated device is incorporated with the timer or distributor. As this depends upon the speed of the motor for its operation, the ignition timing is always at the point of extreme retard when the motor is stopped, so that it may be cranked by hand without taking any precautions to retard the spark. The device is practically a small centrifugal governor the weights of which expand against the action of a spring under the influence of increasing speed. These weights are connected by a lever to the timer, or distributor housing, so that, as they expanwith increasing speed, they move the housing in the proper direction to advance the time of ignition. The spring automatically returns the housing to the retarded position when the motor slows down or stops. The automatic-advance device is a feature of the Atwater Kent battery system, and is also employed on one of the types of Eisemann magnetos particularly designed for use on commercial vehicles. It relieves the driver of the necessity of giving any attention to this part of the control, as the time of ignition is always proportioned exactly to the speed.

Q. When all other factors are fully up to requirements, such as proper carburetion, valves recently ground, spark-plug points not too far apart, and property fitting pistons, but the motor fails to operate with the same "snap" and power it delivered when newer, what is likely to be the cause?

A. Wear in the linkage connecting the spark-advance lever with the timer, the breaker box of the magneto, or the distributor of a modern battery system, is responsible for so much lost motion that the full movement of the spark-advance lever is no longer being transmitted to the ignition apparatus. In other words, the full advance of the spark lever on the steering wheel no longer represents the maximum advance at the timer or distributor, so that the motor is not firing as early as it should and a considerable percentage of the energy, represented by exploding a fully compressed charge, is being wasted. The effect is the same as loss of compression from any other cause.

Q. When the motor will run slowly at one moment and then speed up to the racing point without any apparent cause, then drop off again to slow speed, what is likely to be the cause?

A. Unless this is directly traceable to a partially clogged carburetor jet or a loose throttle which is jogged open and closed by the vibration, the wear mentioned above may be responsible. The spark-advance linkage has become so loose through wear that it no longer holds the timer or distributor at the point to which the lever is moved on the quadrant on the steering wheel, and the vibration of the motor moves it back and forth, advancing it at one moment and retarding it the next.

Q. When the motor does not respond at all to the movement of the spark-advance lever, what is the trouble?

A. There is an actual break between the lever on the steering wheel and the timer, or distributor, or the breaker box of the magneto. This is apt to leave the ignition timing fully advanced, making it dangerous to attempt to start the motor by cranking it on the battery.

Q. Why do some motors require a greater amount of ignition advance than others?

A. Because of their greater speed or the increased amount of lag in the ignition system which must be compensated for by the timing.

Q. What system of ignition has the greatest amount of lag, and which the least?

A. The old battery system, using a roller-contact timer and vibration coils, has the maximum amount of lag, as there is both a mechanical and an electrical lag. The high-tension magneto and the modern battery system are great improvements in this respect, and there is not much choice between them on this point. As an illustration of the effect of the motor speed on the amount of advance required, the Packard "twin-six", using a modern battery system, requires as much advance as the old Packard "four", on which a low-tension magneto was employed; while the Packard six-cylinder motor, which was fitted with a high-tension magneto, required considerably less than either of these.

Q. Why is it necessary in some ignition systems to set the spark "late", or after the piston has actually started downward on the firing stroke, when the spark lever is at the point of maximum retard, while in others it is only necessary to set it at upper dead center?

A. This is due to the difference in the amount of lag, and also to whether a battery or a magneto is employed. It is necessary to insure safety in hand cranking, as, where the lag is reduced to the minimum, the explosion would take place before the piston had reached a point where it could start downward on the firing stroke, and a back kick would result.

Q. Is the piston actually at upper dead center for ignition-setting purposes when it has ceased to rise?

A. No. There is an interval in the revolution of the crank during which the piston does not move, i.e., while the crank is moving in practically a horizontal plane, and it should complete this part of the revolution, so that the piston is just on the point of starting downward again before it reaches the proper point for ignition setting at maximum retard.

Q. What is meant by "fixed" ignition?

A. This refers to those systems in which there is no provision made for altering the time of ignition, either by a manually operated lever on the steering wheel, or by an automatic device for advancing and retarding it. In other words, the time of ignition is fixed and is always the same, regardless of the speed of the motor. It can be used only in connection with a magneto.

Q. What is the ignition-setting point for "fixed" spark?

A. This represents a mean between what would be the points of maximum retard and maximum advance in a variable system. The spark must not occur too late as the motor will develop only a percentage of its power and will overheat; nor must it be too early, as the motor is then apt to fire against the rising pistons when slowed down, as in climbing a hill or when heavily loaded. The magneto must be set, therefore, so that the spark occurs before the piston reaches upper dead center. Just how much in advance of that point the setting should be, will depend upon the motor itself. As will be noted in the table of firing orders, a much greater range of timing is allowed for on some motors than on others, so that there is no rule which will apply to all. The ignition-setting point as given by the manufacturer should be learned and the magneto set in accordance.

Q. Is fixed spark ignition in common use on American cars?

A. Although very largely used abroad, particularly in France, on commercial vehicles such as taxicabs, it has never found favor here and will be found on very few cars.

Q. Is there any other method of checking the ignition-setting point besides the marks on the flywheel or the position of the piston of one cylinder in its relation to the contacts of the interrupter?

A. In some magnetos, such as the Eisemann, there is a setting mark on the distributor of the magneto. When the piston is in the proper position for firing, it is only necessary to bring this setting mark in line with a setting screw on the stationary part of the distributor.

Q. Why do the cylinders of an automobile engine not fire consecutively?

A. Because the pistons are attached to the crankshaft in pairs in the same plane, so that when one piston of a pair is firing the other one is going down on the suction stroke.

Q. How can the firing order of a motor be determined?

A. Take out all the plugs and lay them on the cylinders so that the threaded part of the plug makes contact with the cylinder but the terminal does not. Switch battery on and turn engine over slowly, noting the order in which the sparks occur at the plugs. Watch the valve stems; after the inlet valve of cylinder No. 1 has opened and closed, it is ready to fire. The plug at which the spark then occurs is the proper plug for the first cylinder. The next plug to spark belongs to the cylinder whose inlet valve has just closed.

Q. When a motor will not start, but fires once or twice and then stops, the flywheel rocking back and forth, what is the cause?

A. Some of the spark-plug leads have been misplaced, so that after one or two explosions, the next one takes place out of sequence.

Q. How many different firing orders are possible in a motor?

A. This depends upon the number of pairs of cylinders in a motor, as the two cylinders of a pair cannot fire consecutively, so that the ignition alternates from one pair to another. For example, in a four-cylinder motor, cylinders No. 1 and No. 4 constitute one pair, in that they are attached to crankpins in the same plane, i.e., they rise and fall together; cylinders No. 2 and No. 3 constitute the other pair. Consequently, starting with cylinder No. 1, there are only two firing orders possible in a four-cylinder motor, as follows: 1-2-4-3, or 1-3-4-2. By starting with cylinder No. 2, as the first to fire, two more orders may be used, as 2-1-3-4 or 2-4-3-1. It will be apparent, of course, that the last-named combination is merely the reverse of the second one given above, i.e., 1-3-4-2. In this way, the total number possible with a motor of this type is eight firing orders.

Q. Do motors differ much in this respect, or are firing orders pretty well standardized?

A. Of the eight possible firing orders that may be used in a four-cylinder motor, only two are in common use, viz: 1-2-4-3, and 1-3-4-2. This is because the selection of cylinder No. 1 as the first to fire renders it easier to set the ignition timing, as the piston of the first cylinder is usually more accessible than the others. There are some exceptions to this, the 2-1-4-3 firing order having been used by one or two makes of cars for several years; but the two mentioned above are in such general use as to be considered practically standard.

Q. How does the firing order of a six-cylinder motor differ from that of a four?

A. It is exactly the same in principle, as the six consists of three pairs of cylinders, the pistons of which are attached in couples to the crankshaft, 120 degrees apart; in other words, a three-throw crankshaft, instead of the *two-throw* of the four-cylinder motor, in which the cranks are 180 degrees apart. *Pairs of cylinders,* in this connection, has no reference to the manner in which they are cast, but refers simply to their relation to the crankshaft, which, in turn, affects their firing order. The ignition must accordingly alternate from one pair to another in exactly the same manner as in the four, but a greater number of combinations is possible as there are three pairs of cylinders.

Q. What are some typical firing orders for six-cylinder motors?

A. As in the case of the four-cylinder motor, the use of cylinder No. 1 as the starting point has been practically standardized, hence the firing orders in general use begin with it, as: 1-5-3-6-2-4, or 1-4-2-6-3-5.

Q. How does the firing order of an eight-cylinder motor differ from that of a four?

A. In view of the fact that the usual V-type eight-cylinder motor is nothing more nor less than two four-cylinder motors working on the same crankshaft, or, as it may be better put, with a common crankshaft, the firing order is simply that of two four-cylinder motors in which the ignition alternates from one motor to the other. That is, in addition to alternating from one pair of cylinders to the other, as already described, the firing also must alternate from one group of cylinders to the other, so as to maintain the impulse balance of the motor. The explosion in a right-hand cylinder must always be followed by the firing of a left-hand cylinder.

Q. What are the usual firing orders of eight-cylinder motors?

A. The same as those for fours, i.e., 1-2-4-3 and 1-3-4-2, alternating from one group of four cylinders to the other, as, for example, L1-R3-L2-R1-L4-R2-L3-R4, or R1-L4-R3-L2-R4-L1-R2-L3. The number of combinations is increased as the firing order may start with the first right or the first left cylinder.

Q. How does the firing order of the twelve-cylinder motor differ from that of the six?

A. It bears the same relation to the six that the eight does to the four. In other words, the twelve-cylinder motor is practically two six-cylinder motors, or two groups of six pistons each, working on a common crankshaft.

Q. Give the firing orders of two of the twelve-cylinder motors now in use?

A. The Packard twin-six firing order is R1-L6-R4-L3-R2-L5-R6-L1-R3-L4-R5-L2. That of the National twelve is R1-L6-R5-L2-R3-L4-R6-L1-R2-L5-R4-L3.

Q. What is the effect of a cylinder firing out of order?

A. The spark may either occur when there is no gas in the combustion chamber, in which case that cylinder will miss when it should fire, or it may take place in a cylinder that will be fired so as to act *against* the other cylinders instead of *with* them. In either case, irregular running will result. Where there are either eight or twelve cylinders, the fact that one is either missing or firing against the others will not stop the operation of the motor; the misfiring of a single cylinder in a twelve is scarcely perceptible, except at low speeds. But in a four or six, the misplacing of a pair of spark-plug leads will prevent the running of the motor altogether.

Q. Is it possible to have one cylinder fire out of order?

A. It will be evident that, as the cylinders in all automobile motors fire in alternate pairs, the misplacing of one spark-plug lead naturally involves the dislocation of its mate or its alternate. Consequently, one cylinder cannot fire out of order alone; two will always be affected. For example, in a four-cylinder motor, if the secondary cable to the plug of cylinder No. 1 is connected to the spark plug of cylinder No. 2, it is apparent that No. 2 also must be misplaced. Granted that there is no other fault in this respect, it will be found connected to the plug of No. 1.

Q. Give a typical example of misplaced spark-plug leads causing improper firing order and its consequences?

A. Take the instance cited above. Cable No. 1 has been connected to cylinder No. 2; cable No. 2 has been connected to cylinder No. 1. The firing order is 1-2-4-3, which means that when the piston of cylinder No. 1 is going down on the power stroke, the piston of cylinder No. 2 is drawing in a fresh charge of fuel mixture through the open inlet valve. But, as cable No. 2 is connected to cylinder No. 1, no spark takes place when the piston finishes its upward travel on the compression stroke, and no explosion results. The spark instead of occurring in cylinder No. 1, takes place in cylinder No. 2, and may ignite the incoming gas, resulting in a weak explosion or a back-fire through the inlet valve. If the placing of the inlet valve be such that the incoming charge is not fired by the spark of cylinder No. 1, but takes place in cylinder No. 2, on the suction stroke, nothing will occur in cylinder No. 2, either. When its piston comes up on the compression stroke ready for firing, the spark occurs in cylinder No. 1, and the fresh charge passes out of the exhaust valve of cylinder No. 2 without being fired. In other words, both cylinders No. 1 and No. 2 miss. Cylinders Nos. 3 and 4 being connected up in the proper order, however, they will fire as they should, but in a four-cylinder motor they are not sufficient to keep the motor turning over steadily. It will give two jerky explosions and stop. After cranking several times, cylinder No. 2 will become more or less filled with fresh gas, and a back-fire will result at every other revolution, or every time it is the turn of cylinder No. 2 to fire. Cylinder No. 1 is not likely to back-fire, since the spark is occurring in its combustion chamber on the exhaust stroke.

Q. What would be the effect if, instead of connecting to cylinder No. 1, the lead of cylinder No. 2 misconnected to No. 3?

A. As the firing order of the motor is 1-2-4-3, it will be evident (the other cables being correctly connected) that cylinder No. 1 will fire properly; No. 2 will miss; No. 4 will fire properly; and No. 3 will either miss or back-fire; so that the motor as a whole will run very jerkily; although it will continue to run on this combination, i.e., one operating cylinder in each alternate pair firing a revolution apart. In this case, when the piston of cylinder No. 2 has just finished compressing its charge and should fire it, its spark takes place in the combustion chamber of cylinder No. 3, which is then exhausting, so that it is also much more likely to miss than to back-fire. The effect will be practically the same as if no spark at all took place in either of these two cylinders, and the motor will run on one pair alone.

Q. Is it any more difficult to locate trouble due to the cables being connected in the wrong firing order, in motors having six, eight, and twelve cylinders?

A. The greater number of cylinders would naturally add to the confusion, and the fact that it is not easy to tell off-hand when one cylinder in an eight or twelve is missing, contributes to the difficulty of locating the one at fault. On the other hand, however, the spark-plug leads are so designed that it is much more difficult to connect them up in any but the right way, as they are cut to exactly the proper length and are usually numbered in addition. The contacts of the distributor are also identified in the same manner, so that the connections may be readily checked without making tests of any kind; it is only necessary to trace the cables from the distributor to the plugs. The fact that the motor will continue to run on a pair of cylinders, even though its leads should be misplaced, is misleading, as the missing, or faulty running, is likely to be ascribed to a poor spark plug or something of that nature rather than to the real cause.

Q. Can the firing order of the cylinders be disarranged in any other way than by the misplacing of the secondary cables connecting the distributor to the spark plugs?

A. No. Since the timer, in the case of a timer- and four-vibrator-coil ignition system, as on the Ford, or the distributor, as on a magneto or battery-ignition system, makes its contacts consecutively. That is, on a four-cylinder timer or distributor, the contacts occur in the order 1-2-3-4 and, unless the leads are properly connected up, the sparks will occur in the cylinders in the same order. To obtain the firing order mentioned in a previous query for a four-cylinder motor, i.e., 1-2-4-3, contact No. 1 of the distributor is connected to cylinder No. 1, contact No. 2 to cylinder No. 2, contact No. 3 to cylinder No. 4, and contact No. 4 to cylinder No. 3. The connections would naturally be the same in the case of a timer, as there is then an independent induction coil for each cylinder of the motor.

Q. Has grounding or short-circuiting of the secondary leads any effect on the firing order of the motor?

A. This may be the case where two secondary cables touch each other and there is a short-circuit at the point of contact. For example, assume that the cables of cylinders No. 1 and No. 2 cross each other in running from the distributor to their respective spark plugs (this is poor practice in wiring, but it is nothing unusual to see it on old cars) and that there is a leak in their insulation at this point. After being in service for some time, spark-plug points burn away unevenly, so that the gap at one is less than at the other. Consequently, there will be less resistance at this plug than at the one with the wider gap; in short, the combined resistance of the leakage gap where the cables cross and that of the spark plug with the smaller opening may be less than that of the plug which has burned further apart. Then the current intended to produce a spark at this plug will leak through the insulation and produce a spark at the other plug instead, and the latter will fire out of order while the first plug will miss.

Q. Does a change in the firing order of a motor have any effect on its running? For example, assume a four-cylinder motor designed to run with the firing order of 1-2-4-3. Will such a motor run any better if the firing order be shifted to 1-3-4-2, or to 2-1-3-4? Can this be done easily?

A. So far as the actual operation of the motor is concerned, such a change would have no particular effect, as a cylinder of each alternate pair would fire consecutively. The change can be made without any difficulty, on the average motor, by providing new secondary cables, as the latter are usually cut to about the right length to reach from the distributor to the spark plugs in the firing order for which the motor is originally designed. Then connect distributor contact No. 1 to cylinder No. 2, contact No. 2 to cylinder No. 1, contact No. 3 to cylinder No. 3, and contact No. 4 to cylinder No. 4. Of course, to make the valves function to correspond to this new firing order, the camshaft must be readjusted.

Q. Why do different manufacturers adopt different firing orders, if there is no particular benefit to be derived from one as compared with another?

A. Chiefly to adapt the wiring more conveniently to the location of other essentials, such as the magneto or the distributor of a battery system, although the intake manifold design may influence the choice.

SPARK PLUGS

Q. What are the usual causes of failure of the spark plug?

A. An accumulation of carbon on the inner end of the porcelain and the shell, causing a short-circuit; broken porcelain; points burned too far apart to permit spark to pass.

Q. When there is a hissing noise at the plug, or when oil squirted on it bubbles violently with the motor running, what does it indicate?

A. Either that the porcelain of the plug is not screwed down tightly on its gasket on the shell, the porcelain is broken, or the plug itself is not tight in the cylinder.

Q. What is the cause of a discharge across the porcelain of the plug?

A. The points are too far apart, or the porcelain is broken; usually the former. This usually will be noted only on plugs having very short porcelains as where the latter are long, the distance is much greater than the maximum to which the points can be separated and any spark that would occur owing to the latter cause would take place at the safety gap.

Q. Why is it that when a good spark will occur between the points of a plug in the open air, an equally good spark cannot be obtained in the cylinder with the same distance between the points of the plug?

A. Compressing air increases its resistance to the electric current, so that a stronger current is necessary to produce the same spark under compression in the cylinder, as may be obtained in the open air with less current. This is one of the symptoms of a weak starting battery (dry cells). All the plugs will spark satisfactorily when removed from the cylinders, but it is found very difficult to start the engine by cranking. When fresh cells cannot be had, it may be overcome temporarily by adjusting the points of the plugs closer together, in this way obtaining a satisfactory spark with less current.

Q. What is the proper distance between the points of the spark plugs?

A. For good working with a magneto, this should not exceed $\frac{1}{32}$ inch. With storage-battery ignition, it may be greater, but it is good practice to employ the smaller gap with either.

Q. How rapidly do the electrodes of the spark plugs burn away, and what effect does this have?

A. This will depend upon the plugs themselves and the character of the current supply. The cheaper plugs with ordinary iron-wire electrodes will burn away very rapidly, becoming much too widely separated in a few weeks' use. With better grade plugs, using a hard alloy for the electrodes, the time will depend more or less on the magneto, or where a storage battery is employed, on the coil. Some produce a very much hotter spark than others and, consequently, burn the plugs away that much sooner; but a good plug ought not to need adjustment under two or three months of ordinary running. The fact that the plug points have burned too far apart will be evidenced by a very perceptible falling off in the power; by missing spasmodically in different cylinders at low speeds; and by an occasional discharge across the porcelain on the outside of the plug, if the latter is of the short type.

Q. What can be done when there is an escape of compression around the porcelain of the plug?

A. If the porcelain is not broken, this can be remedied by turning down the gland or packing nut which holds the porcelain in the metal shell. There is an asbestos washer under this packing nut, and tightening the latter causes it to fill completely any space between the porcelain and the shell. The nut should be given only a fraction of a turn, and the tightening should be done when the plug is cold; if it is tightened when very hot, the contraction due to the cold is liable to crack the porcelain.

Q. What is one of the commonest ways of breaking spark-plug porcelains?

A. The use of a big wrench in putting the plugs into the cylinders. Only a spark-plug wrench or a small wrench having but a 3-inch or a 4-inch handle should be employed. The leverage available with the big wrench is so great that the porcelain is crushed, frequently without the knowledge of the man using it.

Q. How can a broken porcelain be detected?

A. Usually by grasping the plug between the fingers and trying to turn the porcelain sideways or to revolve it. Any play is generally an indication that the porcelain is broken, though sometimes they will loosen up so much under the influence of vibration that they may be turned easily with the fingers. Tightening the packing nut will overcome this. Where this treatment does not locate a break, squirting a little oil on the porcelain while the motor is running will do so.

Q. How long should a good plug stay in service?

A. This is hard to average, but with occasional adjustment of the points, a good plug will frequently continue to give satisfactory service for several thousand miles; some have been known to run for well over 10,000 miles, and still continue to operate satisfactorily. When the motor does not run properly and the plugs are suspected, it is better to try the effect of a new set and note the running of the motor carefully, before discarding the old ones, as the fault will frequently be found elsewhere. The first thing that many repair men do with a motor that is a bit off is to throw away a perfectly good set of spark plugs.

Q. What is a "series"-type plug, and what advantages has it?

A. This is a type of plug fitted with two insulated terminals, instead of one, as in the ordinary type, as it does not make a ground connection on the motor by being screwed into the cylinder. It is intended to be used in series with an ordinary plug, hence the name. The current passes through the series plug first, and then, through the second plug of the ordinary type, to the ground, thus producing two sparks instead of one. The advantages claimed for its use are a more rapid and thorough combustion of the mixture, due to the spark occuring at two widely separated places in the combustion chamber; but, in actual practice, the gain is not sufficient to warrant the extra complication, so that this type of plug is seldom used.

Q. What is the object of fitting a plug with several sparking terminals, or electrodes?

A. The current will always follow the path of least resistance and will accordingly bridge the smallest gap. The sparking will start at this gap and, when that particular electrode burns away, will shift to one of the others until that has also burned too far open, i.e., until its resistance becomes greater than that of the next one, and so on. Such a plug should stay in service longer without the necessity of adjusting the gap, but, apart from this, it has no particular advantage, as the short-circuiting of one of the gaps renders all of them useless.

Q. What threads are generally used on spark plugs, and which thread is to be preferred, from the repair man's point of view?

A. Half-inch iron pipe, metric and S.A.E. standard. Plugs with iron-pipe threads are employed only on the cheaper cars; metric-threaded plugs will be found on foreign cars only, and S.A.E. standard plugs ($\frac{7}{8}$ inch-18) on most, if not all, of the better American cars dating from about 1913 on. All work equally well so far as holding compression is concerned. The iron-pipe plug is likely to cause trouble in this way sooner than the others, as they do not depend upon the thread itself to prevent leakage. The S.A.E. standard plug is preferable, being a better mechanical product than the iron-pipe plug as the threads of the latter are not so accurate, and the plug itself is usually not so well made.

Q. When a spark plug leaks at the base, i.e., at the point where it is screwed into the cylinder, what is the cause?

A. If of the iron-pipe type which depends entirely upon its tapered thread to hold the compression, a section of the thread may have been damaged in handling. With either of the other types, the plug may not be seated snugly enough on its gasket, in which case a quarter-turn in will usually remedy the leak. If it does not, the gasket should be replaced with a new one.

Q. Is there any danger of turning an iron-pipe plug in too tightly?

A. If screwed home too tightly while the motor is hot, the plug may bind and become very difficult to remove, sometimes necessitating drilling it out and re-tapping the hole.

Q. Is the priming type of plug of any particular advantage?

A. On low-priced cars not fitted with pet cocks in the cylinders, it is an aid to starting in cold weather; though, as a matter of fact, the priming inlet of the plug is likely to become clogged with soot, so that it cannot be used for injecting gasoline into the cylinders.

Q. Why has the magnetic type of spark plug not come into general use?

A. It is an expensive type of plug to make and is more subject to derangement than the ordinary kind. It is only intended to be used with a low-tension magneto and plain-spark coil (single winding on an iron core), and this type of magneto has long since become obsolete on the automobile.

Q. Is porcelain or mica preferable, as the insulator of the plug?

A. While mica is practically unbreakable, it is liable to become saturated with oil and dirt, causing leaks that are hard to trace; so that the use of porcelain is preferable, despite its liability to breakage.

Q. Is changing from one make of plug to another likely to cause any difference in the running of a motor?

A. As the power of the motor is dependent, to a very large extent, upon the proper ignition of the charge, a change from one make of plug to another will sometimes make a very marked difference. Because of the great amount of variation in the width of the cooling jacket and the thickness of the cylinder walls, certain types of plugs are particularly adapted to certain makes of motors. In fact, the plugs have been designed especially for service on those motors. For example, some motors require an unusually long plug to permit of the sparking points extending well into the combustion chamber. In others, a plug of this type might interfere with the piston when at upper dead center. Always use the type of plug recommended by the manufacturer of the car.

Q. What is the cause of the spark plugs in a motor becoming fouled very rapidly?

A. An excess of lubricating oil is finding its way into the combustion chamber, and its burning there deposits a heavy layer of carbon on the ends of the plugs. This may be due to leaky piston rings; the use of improper oil for the motor, as where a very light oil, instead of a heavy bodied lubricant is used in a motor intended for the latter; or, in old cars, the lack of baffle plates between the crankcase and cylinders. Running the motor with an over-rich fuel mixture will also cause sooting of the plugs. The use of a heavier oil and with it a certain proportion of flake graphite, or "Gredag", will often greatly improve the compression of an old motor and effectively remedy this trouble.

Q. Is it advisable to use lubricating oil mixed with graphite in all old cars?

A. It is usually good practice, except on the Ford, as the magneto of the latter runs in oil splashed back from the crankcase, and the presence of graphite in this oil would short-circuit the magneto. In case this has been done on a Ford, it would be necessary to wash

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the magneto out very thoroughly with gasoline to remove all traces of the graphite, and even that might not remedy the short-circuiting.

Q. When the plug in only one cylinder of a motor continually soots up very rapidly, what is the cause?

A. That particular cylinder is being flooded with oil, and an excess amount of it is reaching the combustion chamber. A piston ring may have broken in that cylinder, the rings may have worked around until their openings are in line with one another, or the supply system may have become deranged, causing an excess of oil to reach the section of the crankcase directly under that cylinder.

Q. Is there any way of knowing to a certainty before undertaking an inspection, whether missing is due to a faulty plug or to some derangement of the carburetor?

A. If the miss continually occurs in the same cylinder, it may be put down as due to the plug or wiring of that particular cylinder, even though the plug, when tested from the outside (i.e., without removing it from the cylinder), is apparently working properly. When the missing is spasmodic, occurring first at one cylinder and then at another, it is more likely to be due to faulty carburetor adjustment or a partially clogged carburetor nozzle. A weak dry battery, however, will produce similar symptoms; failing fuel supply also will, though, in this case, the whole motor will run jerkily one moment, speed up the next, and then almost stop, only to repeat the performance.

Q. Is the usual test, made by unclipping the secondary cable from the plug and holding it near the terminal with the motor running, always conclusive as to the proper working of the plug, when a spark occurs between the two?

A. No. Since a short-circuited plug will not prevent a spark from passing between its outer terminal and the end of the cable held near it. The gap made by disconnecting the secondary cable and holding it a short distance away has simply taken the place of the gap which should exist between the plug points. This test is conclusive only as to the proper functioning of the distributor and the integrity of the wiring connecting that particular plug.

Q. When the motor misses spasmodically, and there are intermittent discharges of high-tension current at different points on the cylinders, while it is running, what is the cause?

A. Moisture. The secondary cables have become wet enough to cause leakage of the high-tension current; usually the result of the careless use of the hose in washing. The only remedy is to run the motor continuously until the heat dries things out thoroughly.

Q. When no spark plug is obtainable at any of the plugs, so that the motor cannot be started, in what order should the cause of the trouble be run down?

A. If a dry battery is used as the source of current, first see that it is not exhausted by testing with a small ammeter. Each cell should show 10 amperes or more. If one is considerably below the others, it reduces them to its level. Where a storage battery is used, switch on the lights as a test. They should burn brightly. Provided there is no failure of the current, inspect the interrupter, or contact breaker; see that its points separate when the high part of the cam strikes the arm carrying the movable point. If they do not separate, no current is induced in the secondary winding, and an adjustment of the points, to open about the space represented by an ordinary visiting card, will remedy the trouble. If the points open properly, inspect the wiring and connections between the interrupter and the battery. Should both the interrupter and its wiring be O. K., note whether the ground connection from the coil is fast. Failing all of these, inspect the high-tension distributor. This is about the order in which the trouble would be likely to occur.

Q. When the motor continues to run after the current has been turned off, what is the cause?

A. The cylinders have become so hot, due either to lack of oil or or low water in the cooling system, failure of circulation, etc., that either the spark-plug electrodes have become red hot, or particles of carbon, deposited in the combustion chamber, have become incandescent, thus firing the charge. The fuel supply must be shut off and the motor allowed to cool.

Q. Should the motor back-fire when attempting to start, even though the spark-advance lever has been pulled back as far as it will go, what is causing the trouble?

A. The linkage connecting the spark-advance lever with the breaker box of the magneto or of the interrupter (battery system) has parted at some point, so that it no longer moves the breaker box to retard the time of ignition.

REGULATION DEVICES

Interrupters and Timers

Q. How does an interrupter operate?

A. It is normally closed, short-circuiting the battery on the primary winding of the coil until just before it is necessary for the spark to occur in the cylinder; a cam then separates the contact points, and the high-tension current induced in the secondary winding of the coil jumps the gap of the plug. In the case of a magneto, the winding of the armature is short-circuited on itself to permit it to "build up", so that when the interrupter contacts are opened by the cam, the peak or highest value of the current wave generated is utilized. The opening of the circuit in either case occurs at the same time the distributor arm is passing one of its contacts.

Q. How does a timer operate?

A. Contacts, insulated from each other, their number corresponding to the number of cylinders, are located at equidistant points on the inner circumference of the timer housing, while the shaft carries a single contact which in its revolution successively touches each one of the stationary contacts. Where separate vibrator coils are used, as on the Ford, each stationary contact corresponds to one of the coils.

Q. Do interrupters and timers fail from the same causes, and what are they?

A. No. The cause of failure in one case is the reverse of that in the other. An interrupter fails when it does not open the circuit, and a timer when it does not close it. Dirt and wear are the usual causes of failure in both cases; moisture is also responsible at times. Test by having an assistant turn the engine over slowly by hand and watch the operation of the interrupter; if the cam fails to separate the contact points, true up their faces with fine sandpaper and test again. (This does not apply to Atwater Kent interrupters. See description.) Stop with the cam in the opening position and see if a sheet of ordinary paper can be slipped between the contacts. See that there is not an excess of oil in the housing, as oil on the contact point insulates them. In the case of a timer, see that the spring of the movable contact has sufficient tension to keep it pressed firmly against the stationary contacts as it revolves; note whether sufficient wear has occurred to cause poor contact even with sufficient spring pressure.

Q. How far should the contacts of an interrupter separate?

A. This differs somewhat with different systems, but in the case of the interrupters used on battery systems, it is very small, seldom exceeding a few thousandths of an inch. In the case of the Atwater Kent interrupter, this is .010 to .012 inch. (Coated catalogue paper is .005 to .007 inch thick; a thin visiting card is .010 to .015 inch thick.)

Q. How does the Atwater Kent interrupter differ from other battery interrupters?

A. The circuit is normally open and only remains closed momentarily before being opened by the dropping of the lifter into its notch on the shaft.

Q. Can this interrupter be tested in the same way as that just described?

A. No. The movement of the lifter in striking the latch to close the circuit is so rapid that it cannot be detected with the unaided eye, even though the engine be turned over very slowly by hand.

Q. What will cause this interrupter to fail?

A. Wear of the lifter to an extent where it will not engage the notches of the shaft properly, usually caused by lack of oil. Other causes of failure are the same as for other types, generally worn or burned contact points.

Q. When the contact points of an interrupter of any type burn away very rapidly, what is the cause?

A. The condenser has broken down so that it is no longer protecting the points from the full heating effect of the arc formed at the time of breaking the circuit. Use the testing-lamp outfit described in connection with lighting and starting systems. Apply one point to each of the condenser terminals; if the lamp lights, the condenser is short-circuited. The only practical remedy is replacement by the manufacturer, as even the best equipped garage is seldom fitted to take care of such work.

Q. Does discoloration always indicate burned contact points, and how often should these points require cleaning and adjustment?

A. No. According to the particular alloy used in the contacts they will assume a bright purple, an orange, or a gray tinge. The squareness of their surfaces and the contact they make when together are the best indications of whether attention is needed; if pitted or high on one side, truing up will be necessary. Unless the condenser has failed, they should not require attention oftener than once a season, or say 6000 to 8000 thousand miles' running.

Distributors

Q. What is the function of the distributor and how does it differ from that of the interrupter and timer?

A. At the same moment that the interrupter opens the primary circuit of the coil, or the timer makes it in the case of a vibrating coil, the distributor makes contact with a stationary segment representing a spark-plug terminal. The distributor accordingly is said to run synchronously with the interrupter or timer. It is practically a duplicate of the timer designed to handle a high-tension current, in that it has one revolving contact and a stationary contact for each cylinder.

Q. Does the moving member of a distributor actually make contact with the stationary contacts, as in the timer?

A. No. This is not necessary owing to the high voltage of the current. The moving member passes very close to the face of the stationary contact but does not actually touch it; thus avoiding wear. This applies, however, only to those early-type magnetos or to separate distributors employing a metal moving contact. Where carbon brushes are employed, they are pressed against a fiber disc with a metal segment countersunk flush with its face and this segment passes under each carbon brush in rotation.

Q. What are the usual causes of failure in a distributor?

A. Short-circuits, due to moisture, dirt, or carbon dust. Owing to the high voltage of the current it will leak across barely perceptible paths caused by dampness or carbon dust.

Q. What is the so-called ignition unit of the modern battery system?

A. This is a combined contact breaker and distributor similar to the contact breaker and distributor of a magneto—in other words, a magneto minus the current-generating end. It is mounted on a vertical shaft and is driven through bevel, or helical gearing, from either the camshaft or one of the auxiliary shafts of the engine (i.e., water pump or magneto-drive shaft). The contact breaker is placed directly below the distributor, the secondary cables coming out of the upper face of the latter. (See description of Westinghouse and Connecticut units.)

Q. What is the "unisparker"?

A. This is the Atwater Kent ignition unit and is similar in general design to those referred to above but it is an "open-circuit" type, while they are "closed-circuit". The term is a trade name derived from the fact that the contact breaker makes but a single spark, as compared with the vibrator coil which produces a series of sparks only one of which, however, is available for ignition. All contact breakers on magnetos and, as now used, on modern battery systems, produce but a single spark. The time of ignition is so limited on a high-speed engine, that, if this single spark fails to ignite the charge in the cylinder, subsequent sparks are of little value, as the piston is already well down on the firing stroke by the time a later spark occurs, and much of the force of the explosion is lost.

Q. How is the time of ignition advanced and retarded on the ignition unit?

A. Usually by altering the relation of the moving contact of the distributor to the stationary contacts. The distributor plate, i.e., the insulating disc carrying the stationary contacts is connected to the spark-advance lever on the steering column, and it may be moved part of a revolution backward or forward to advance or retard the time of ignition. To alter the timing, the position of the moving contact on its driving shaft may be shifted. For example, in the Delco distributor a central screw in this member is loosened, and the contact may then be moved in either direction with relation to the shaft.

Switches

Q. What is a "reversing" switch and why is it employed on ignition systems?

A. It is a double-contact switch which reverses the polarity of the current, i.e., its direction, through the contacts of the interrupter every time the switch is closed. This is done to prevent the burning away of the contact points in one direction which would cause a peak to form on the positive and a crater, or depression, on the negative. Reversing the direction of the current causes the points to become alternately negative and positive in accordance with the position of the switch.

Q. What is the nature of the trouble ordinarily to be looked for in a switch?

A. Poor contact due to wear or weakening of the spring; broken or frayed connections causing a ground or short-circuit.

Q. What is an automatic switch?

A. This term is frequently applied to the battery cut-out of the lighting and starting system. On the Connecticut ignition system, it is a thermally operated switch, designed to open the circuit when the switch has inadvertently been left on after the engine has stopped.

Q. Are there any troubles peculiar to automatic type of switch?

A. None that is not equally so of any similar device such as the battery cut-out or the circuit breaker.

Coils

Q. How many different types of coils are employed in connection with ignition systems?

A. Three. The first and simplest of these is usually termed a *spark coil,* and consists of a single winding of coarse wire on a heavy iron wire core. It acts by self-induction, the circuit remaining closed long enough to permit the core to become thoroughly magnetized; the energy thus stored in the core being released when the circuit is broken again. This gives increased voltage at the spark plug and causes an "arc" rather than a spark at the latter when the terminals of the plug are separated. This type of coil is only employed in connection with low-tension or mechanically operated spark plugs, and this system is now used on stationary engines and motor boats exclusively, having long since become obsolete on the auotomobile.

The other two types are known as induction coils, and differ merely in one being fitted with a vibrator while the other does not require this attachment to operate it. The induction coil is a miniature step-up transformer. It consists of a core of iron wires on which the primary of two or three layers of No. 16 or No. 18 wire is wound almost the full length of the core, and a secondary of many thousand turns of very fine wire, such as No. 36 or 38 B. & S. gage, or even No. 40, which is almost as fine as a hair. In coils of the best construction, this fine wire is wound in pancakes, or narrow sections, several of which are necessary to complete the secondary. Their terminals are connected in series thus making practically a single winding. Heavy insulation is placed between the primary and secondary windings, and the containing case is usually filled with an insulating compound, melted into it and becoming solid when cold.

Q. Why is an induction coil termed a "step-up" transformer?

A. It literally steps up or raises the voltage of the current sent through it. The primary winding is connected to the source of current and the secondary to the spark plugs through the distributor.

Q. Is the action of the coil based on the same principle as that utilized in generators and motors?

A. The principle of induction, as explained in Part I, is the same in all three, though it is utilized in a different manner in the induction coil. Instead of a moving coil of wire cutting the lines of force of a magnet, impulses are produced either by sending a pulsating current through the primary winding or by using an alternating current.

Q. How is this pulsating current produced in the primary?

A. By placing a vibrator in series with the primary winding.

Q. Of what does the vibrator consist, and how does it act?

A. It consists of a spring-hinged armature and a pair of adjustable contact points, exactly as in an ordinary electric bell or buzzer. This armature is located directly over the end of the core of the coil and close to it. When a current passes through the primary winding, it makes the core strongly magnetic and attracts the armature. This pulls the latter away from the stationary contact point and breaks the circuit, so that the core is no longer magnetic. The spring immediately pulls the armature back and recloses the circuit, this action taking place at high speed as long as the current is on.

Q. Why is the vibrator theoretically not necessary when an alternating current is used?

A. The rise and fall of the current wave, from zero to maximum and back again in the reverse direction, produces the same effect of magnetizing and demagnetizing the core of the coil very rapidly.

Q. Is the vibrator coil as rapid in action as the induction coil used with alternating current?

A. No. Since there is a mechanical as well as an electric "lag", or delay. The inertia of the armature must be overcome before it can be pulled down by the core, and to do this on a vibrator adjusted to withstand road shocks, the core must become *saturated*, or strongly magnetic. The time necessary to overcome the inertia of the armature is the mechanical lag, while that required for the core to become saturated is the electrical lag. In combination they make the vibrator coil very much slower in action than the other type, and this is greatly accentuated by a stiff adjustment of the vibrator spring.

Q. Why is a vibrator necessary with one type of battery ignition and not with another, i.e., the so-called modern battery ignition?

A. Owing to the type of timer or interrupter, frequently erroneously termed the "commutator", employed on the two systems.

Q. What is the difference between the old-style timer and the modern interrupter?

A. In the former, a long contact is provided for each cylinder and the revolving contact member is in touch with this for quite an appreciable period of time, during all of which the vibrator of a coil of that type is in action. If the contact member of the timer were depended upon to make and break the circuit through the coil to obtain the spark in the cylinder, the stationary contacts in the housing would have to be very much shorter, and no provision for advancing and retarding the time of ignition would be available. Furthermore, the wiping contact of the ordinary style of timer is not adaptable to the extremely rapid make-and-break that is necessary for this purpose. The interrupter of the modern battery system is designed along practically the same lines as the contact breaker used in the primary circuit of a high-tension magneto or the only circuit used on a low-tension magneto. Its parts are made very small and light and with great accuracy, so that its inertia is reduced to the minimum and it will act with extreme rapidity. The gap is so small and the rapidity of action so great that the movement is often not visible to the unaided eye. It is practically a mechanical vibrator designed to give a single make-and-break at exactly the right moment as compared with the electrical vibrator, which must be started well in advance of the moment ignition is required, and which continues in action after the spark has occurred in the cylinder. Consequently, both the mechanical and the electrical lag, which make the vibrator coil comparatively slow in action, are reduced to a minimum, and the amount of current necessary is cut to a fraction of that required by the latter.

Q. How can the speed of operation of a vibrator be judged?

A. By the note it produces in action. A low note well down the scale denotes slow action; the higher the note, or buzzing, the more rapid the vibrator is acting.

Q. What effect on the ignition has the speed with which the vibrator operates?

A. A slow-moving vibrator increases the amount of lag and retards the ignition accordingly. This causes a corresponding reduction in the power of the engine, as the spark does not occur at the proper time to give the best efficiency.

Q. What is a master vibrator?

A. The vibrator type of coil on a multi-cylinder engine requires an individual coil for each cylinder, and it is often found difficult to adjust all of the vibrators so that they will act uniformly. If some are stiffer than others they will not act so rapidly, and the time of explosion in the cylinders they control will be delayed, causing uneven running of the engine. To overcome this, an extra coil with a specially made vibrator is connected in series with the timer and the other coils, so that its vibrators acts for each coil in turn, the vibrators of the other coils either being removed or screwed down hard so that they cannot act. This makes but one vibrator to adjust, instead of the four on a four-cylinder engine. As it controls all of the other coils, it is known as a master vibrator.

Q. Is the vibrator type of coil still in general use?

A. It has long since become obsolete on all cars except the Ford.

Q. As the Ford magneto produces an alternating current, why are vibrator coils necessary?

A. The Ford magneto has sixteen poles, and the armature which serves as the flywheel, carries sixteen coils, so that the number of alternations at the high speed at which the Ford motor runs, is very great. These alternations, or cycles, are so rapid that they overlap each other, as is evidenced by the steady burning of the incandescent headlights. The induction coil does not act quickly enough to be affected by the change of polarity so that a vibrator is necessary on each coil to produce a sufficiently hot spark for ignition.

Q. How can the four vibrators of the Ford coil be adjusted so as to operate uniformly?

A. The fact that they are not doing so, will be evidenced by the uneven running of the motor. Determine, by holding down the vibrators, one after the other, which cylinder or cylinders are lagging behind the others in firing. This will cut out the cylinders in turn; in fact, two may be held down at once, and the action of the remainin pair noted. When the cylinder, or cylinders, at fault have been determined, adjust one at a time by releasing the lock nut of the adjusting screw of the vibrator and turning it up or down, according to whether improvement in running is noted, or not. Usually only a small fraction of a turn one way or the other will be necessary. Turn the screw very slowly and very little at a time and, when the proper adjustment of the screw has been secured, lock in place again securely. Ordinarily, the proper adjustment may be secured simply by noting the running of the motor. When all the cylinders fire regularly and without any apparent lag, the adjustment is considered correct. To secure a finer adjustment, a small portable ammeter, reading by tenths to three or five amperes, may be used. Connect this in series with each one of the coils in turn, and note the reading at which the coil acts most rapidly. The other vibrators may then be adjusted to give the same reading. When dry batteries were relied upon for ignition, this test was employed to reduce the current consumption to the minimum but with the excess supply of current from the Ford magneto, this is not necessary, and the vibrators may be adjusted to the reading giving the most rapid action, regardless of the current consumption. This test may be employed also to check the operation of the magneto, as its current output may have fallen off to a point where it is no longer sufficient to operate the coils satisfactorily.

Q. Why is a vibrator not necessary on the alternating current generated by the ordinary type of magneto?

A. The latter has but two field poles and a single coil on a two-pole armature, so that its cycles are very much fewer in number, and there is definite drop in the current, from the maximum to an absolute zero, twice in every revolution. Assuming a speed of 1200 r.p.m., the ordinary magneto would be running 600 r.p.m., as it is driven by a half-time shaft of the motor. This is 10 revolutions per second times 2 cycles per revolution which gives an alternating current of but 20 cycles, or one which would cause an incandescent lamp to flicker very badly. The Ford magneto, on the other hand, is directly on the crankshaft. Consequently, it is turning 20 revolutions per second, and its coils produce 16 cycles per revolution, or 320 cycles per second, equivalent to 19,200 cycles per minute. For ordinary commercial lighting, only 60 cycles per second are necessary to produce a steady light. The drop to zero in the current curve of the ordinary

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magneto permits the core of the coil to become demagnetized, and it is then remagnetized by the subsequent rise to the maximum value in the other direction, so that no vibrator is necessary to accomplish this alternate magnetizing and demagnetizing of the core which is needed to produce the inductive effect in the coil or transformer.

Q. How many connections are there on a coil?

A. Three; one to the primary, from the battery or magneto; one from the secondary, to the distributor, in the case of a single coil, or to the spark plug in the case of a multiple coil; and one to the ground. The last named is referred to as a common-ground connection, as it grounds one side of both the primary and secondary windings of the coil.

Q. How are these connections made?

A. On the single non-vibrator coil, as used with an ordinary magneto, by means of wire cables from the magneto to the primary of the coil, from the secondary of the latter to the high-tension distributor. In the case of the Ford multiple-vibrator coils, each coil is an independent unit, having brass strap connections attached to the bottom of the coil-unit case. These straps are of spring brass and they bear against corresponding plates of brass in the bottom of the coil box fastened to the dash. Simply lifting the coil unit out of the box breaks the connection and automatically remakes it when the coil is replaced. Due to this type of connection, irregular firing of the Ford motor will frequently be found to result from the cover of the coil box not being snapped down tightly. This permits the coil units to jump around in the box owing to the jolting and vibration, and every time they are jolted up off their connections, a cylinder fails to fire, as the coil does not receive any current. Coils used in connection with modern battery systems are often grounded in the same manner as the magneto, i.e., by their attachment to a plate on the motor the ground wires of the coil being connected to this plate.

Q. When a coil fails to operate, how can it be tested for faults?

A. In the case of the single coil, used in connection with an ordinary magneto, disconnect it and test with the testing-lamp outfit described in connection with lighting and starting systems. Place one of the terminals of the testing set on the common-ground connection, then place the other in turn on the primary and the secondary leads. If the windings are intact, the lamp should light each time.

Should it fail to do so, the covers of the coil may be removed to note if a wire has broken just beneath it. This is most likely to be the case with the secondary, owing to the very fine wire used. If there is no break, either at this point or where the primary lead is connected to its winding, it will be necessary to return the coil to the manufacturer as there is an internal short-circuit, which cannot be repaired in the garage. The only difference between the method above outlined for a single coil and that of a unit-vibrator coil as used on the Ford, is to touch the test points to the brass strap connections representing the different windings.

Q. Why is but one coil used in connection with an ordinary magneto, while four are employed on the Ford?

A. Where a single coil is used, the secondary current is led to a distributor from which it is again led to the various spark plugs in the proper order of firing. No distributor is employed on the Ford, so that a vibrator coil is necessary for each cylinder. The connections from the coils to the plugs are made in the same order as they would be to a distributor.

Q. When a vibrator coil cannot be made to function properly by adjusting the contact screw, what should be done?

A. The contacts should be trued up with a very fine file, as failure to function will usually be caused by their having become badly burned away or pitted, thus making poor electrical contact. Where the above is the case and the contact points are square and true, it is only necessary to clean them by drawing a worn piece of fine sandpaper between them several times, first on one side and then on the other. See that none of the holding screws of the vibrator frame have become loosened, and that the lock nut of the movable contact holds the latter firmly in place when tightened up.

IGNITION BATTERIES

Q. What types of batteries or cells are used for ignition?

A. Dry cells and storage cells, or accumulators. (For queries on the latter see under "Battery" in Lighting and Starting Section.)

Q. What type of cell is the so-called dry cell?

A. It is a primary cell, i.e., one in which a current of electricity is generated by chemical reaction, and is technically known as an "open-circuit" battery.

Q. Of what does the dry cell consist, and how much current does it generate?

A. The elements are the zinc container and a carbon plate centrally placed in the container and insulated from it at the bottom. Around this carbon plate, which constitutes the negative element (the negative element in a primary battery carries the positive terminal and *vice versa*), is packed a depolarizing agent, usually dioxide of manganese. The active solution is sal ammoniac in water which is poured in after the cell is assembled and filled with the depolarizer, and then the cell is sealed at the top with pitch, so that it is dry in name only. No chemical action can take place without the presence of moisture.

A dry cell of the ignition type generates a current of 20 to 25 amperes (when new) at a potential of 1½ volts.

Q. Why is a depolarizing agent necessary?

A. The action of the cell generates hydrogen gas, which quickly covers the carbon plate in the form of globules, rendering it inactive. The cell is then said to be *polarized,* and the current generated drops off very rapidly. This may be illustrated by placing an ammeter across the terminals of a new cell. The ammeter reading will remain at 20 amperes for a short time and then will quickly drop until, at the end of five minutes, the instrument will show scarcely any reading at all. If the connection is broken and the cell allowed to stand for ten minutes, it will again show almost as high a reading as before; at the end of an hour or more of rest, it will give practically the same reading. The depolarizing agent has in the meantime absorbed the gas which prevented the action of the cell.

Q. Why is it termed an open-circuit cell?

A. Because it will only produce its normal output for very short periods and must be allowed to rest between each demand for current. Otherwise, it will quickly become polarized and, if tested in this condition, will apparently be dead. It cannot be used where a steady current is required but must normally stand on open circuit.

Q. How is the dry cell employed for ignition?

A. Four cells are connected in series to give current at 6 volts, and a battery of this type is ordinarily employed, either as an emergency stand-by or simply for starting purposes. Where an open-circuit type of interrupter is employed, such as the Atwater Kent, it may be used as the main source of ignition current; as this interrupter makes instantaneous contact only at the moment the spark is required in the cylinder, the battery otherwise being on open circuit.

Q. How can the life of such a battery be prolonged?

A. By connecting two or more sets of four cells each in series-multiple, i.e., each group of four is connected in series to give the required voltage, and the positive and negative terminals of each group are connected together. The amount of current then drawn from each cell is only one-half what it would be if a single set of cells were employed, or one-third what it would be where sets are in series-multiple, and so on.

Q. When a set of four dry cells will last a certain length of time, why is it that adding extra cells in series, for example, a six-cell battery, will not last longer?

A. The amount of current drawn from the cells when the circuit is closed depends upon the voltage of the entire series, and the greater the total voltage the larger the volume of current, in accordance with Ohm's law. Consequently, the six-cell battery will not last so long as the four on the same service.

Q. Why is it not good practice to connect an old set of four cells in series-multiple with a new four-cell battery, or groups of uneven numbers in the same manner, as for instance, three in one and four in another?

A. The new cells will have an output of twice that of the old ones, so that when the circuit is closed they will discharge through the latter until the amperage of all is equalized. Where uneven numbers are used in groups in series-multiple connection, the voltage of the larger will be superior to that of the smaller, and a similar action will take place on open circuit so that in a short time the maximum potential of the battery will be that of the weakest group.

Q. Why should one cell much lower than the others never be included in a dry-cell battery?

A. For the reason just given above, as well as the fact that an exhausted cell increases the resistance of the battery as a whole and decreases the current.

Q. Why will the dry-cell battery used on a dual ignition system not run the engine satisfactorily for any length of time when the magneto is not in proper working order?

A. Because the interrupter, or contact breaker, of the magneto is of the closed-circuit type, thus drawing current continuously, except when the points open to break the circuit and induce a high-tension current in the secondary of the coil. In a system of this type, the dry cells are intended only for starting purposes.

Q. Why can a modern battery system not be used with dry cells?

A. Because the interrupter is of the closed-circuit type, similar to that of the magneto, and the demand for current (usually about 3 amperes) is practically constant. It is not so much the amount of current required that affects the dry cells, as the fact that they are almost constantly on closed circuit, so that there is no opportunity for the depolarizing agent to work. This demand on the storage battery of the starting and lighting system (usually of 80- to 120-ampere-hours capacity) is negligible. At a 3-ampere discharge rate, the larger battery when fully charged and in good condition would be capable of giving practically forty hours of continuous service. Under the same conditions, new dry cells would not provide efficient ignition for more than an hour.

Q. Does the voltage, as well as the amperage, of the dry cell fall off on closed circuit?

A. The voltage is affected very slightly; a cell that is practically exhausted will show almost 1½ volts so that a voltmeter test is no indication of the condition of the cell.

FORD IGNITION SYSTEM

While a great many of the causes of missing or breakdown, in the ignition system covered by the foregoing queries, apply to a great extent to all cars, such as loose wires, short-circuits and the like, the Ford system is distinctive. It is based on the same fundamental principles, of course, but it has many features not to be found on other cars so that there are causes of failure that could never be readily determined by experience gained on other makes of machines, though long handling of ignition apparatus would naturally be of great assistance. In working on the Ford ignition system it must be borne in mind that it is a combination of the old-time battery system with a modern generator as the source of current supply, so that the many defections due, in the earlier days to the dry battery, are now lacking.

Q. Of what does the Ford ignition system consist?

A. A multipolar alternating-current generator (magneto) built integral with the flywheel; a primary, or low-tension timer, in which a roller makes contact with the four stationary segments in the housing; four vibrator coils, one for each cylinder, plus the usual number of spark plugs and connections in the primary and secondary circuits.

Q. Is the Ford ignition system efficient and reliable, or is it advisable when much trouble is experienced with it to replace it with any of the numerous accessories and complete ignition systems that are claimed to be improvements?

A. While there are many ignition systems the parts of which are made with greater precision, and some in which the design and particularly the accessibility of the important essentials are superior, experience has proved the Ford system to be both efficient and reliable. With proper care, there should never be any necessity for replacing it with any system made by an accessory manufacturer, or for adding to it any one of the legion of devices advertised as improvements on it.

Timer

Q. What are some of the commoner causes of failure of the Ford system?

A. One of the most frequent is due to the timer and is caused by failure to lubricate it. Contrary to the usual practice, which is to prevent oil getting on the contacts of a timer as it tends to insulate the latter, the Ford timer requires plenty of oil, and should be lubricated every day. There is no fear of giving it too much oil as the excess will leak out of the housing; it will continue to operate satisfactorily even though flooded with oil, while the slightest lack of it will cause trouble.

Q. What is the nature of the trouble caused by the timer?

A. If not oiled at regular intervals, it will cause missing of various cylinders, and those that do fire will be late, as if the ignition were fully retarded, so that the motor develops very little power. An accumulation of gummed oil and dirt will produce a similar result. The timer housing should be taken off and the contacts cleaned; the roller contact also should be cleaned by squirting gasoline over it and wiping over well.

Q. Will lack of oil have any other result?

A. Besides the missing, usually most noticeable at higher speeds, failure to lubricate will result in very rapid wear of both the roller and its track (contacts in the stationary housing) so that its operation will soon become unsatisfactory, even though subsequently kept oiled.

Q. What are some other causes of faulty operation of the timer (generally referred to as a commutator)?

A. Weakening of the spring which holds the roller against its track will cause missing at low speeds, while a loosening of the spring which holds the timer housing in place is liable to cause erratic firing at all speeds. This spring is held by a single cap screw passing through the breather tube, which serves also as an oil filler for the crankcase. At its inner end it has a small boss which fits in a corresponding depression in the hub of the timer housing. This is the only thing that holds the latter in place. The loosening of this cap screw is liable to let the housing drop out of place sufficiently to prevent the roller making contact with all of the segments.

Q. Does the weather have any effect on the operation of the timer?

A. Unless precautions are taken to lubricate it properly, cold weather will make starting difficult. This is due to ordinary lubricating oil becoming congealed in the housing, thus preventing the roller from coming into good contact with the segments. An indication of this sometimes is that the motor will fire only on two or three cylinders for several minutes after being started and will thereafter fire regularly, the oil then having become liquefied again.

Q. How can the timer be removed?

A. Take out cotter pin from end of rod which attaches it to the spark-advance lever on the steering column, and detach this rod. Loosen cap screw passing through breather pipe on top of the timing gear cover. This releases the spring which holds the timer housing in place, and the latter can be easily removed. To remove roller contact, unscrew lock nut, withdraw steel brush cap and drive out the retaining pin. The brush can then be lifted from the camshaft. In replacing it, care must be taken not to alter the timing of the ignition. The upper contact of the housing represents cylinder No. 1, and the exhaust valve of that cylinder should be closed when the brush points upward. This may be determined by removing the valve mechanism cover and noting the operation of the valve in question.

Q. If parts show much wear, what should be done?

A. Replace them; as they cost so little that it is far less expense to put in new parts than to attempt to make old ones serve by truing them up.

Q. When examination reveals gummed oil and the weather is cold, what should be done?

A. Clean out the housing and the roller-contact parts with gasoline, and use a mixture of $\frac{1}{4}$ kerosene and $\frac{3}{4}$ lubricating oil in the timer, as long as the weather is cold.

Q. What other causes of trouble with the timer are more or less common?

A. Short-circuiting of the primary wires which lead to the timer, or the loosening of these wires at the terminals on the housing. The position of the timer is such that the insulation of these wires is subjected to considerable wear by reason of the movement of the housing in advancing and retarding the time of ignition. The best method of remedying this is to replace the entire set of primary wires.

Vibrator Coils

Q. Is irregular firing likely to be caused by any other part of the system than the timer?

A. The vibrators of the induction coils may get out of adjustment and cause either erratic firing, or missing of one or more cylinders altogether, in case one or more vibrators cease to operate.

Q. How can this be determined?

A. Run the motor slowly and watch the action of the vibrators; they should act regularly and with the same rapidity in each case, any stuttering or hesitation indicating either poor adjustment or points in poor condition.

Q. How can the vibrators be utilized to determine which cylinder is missing, where the cause lies in some part of the system other than the vibrators themselves?

A. Hold one vibrator down at a time with the finger; if the remaining three cylinders fire regularly, the one represented by the vibrator being held out of action is the one at fault. The cylinder can always be located quickly by holding down each vibrator in turn.

Q. When the cylinders do not all fire regularly, but there is no perceptible difference between the action of the vibrators, how can the cylinder, or cylinders, at fault be determined?

A. Hold down the vibrators in pairs, taking first Nos. 1 and 4, and then Nos. 2 and 3. This will cause the engine to run on two cylinders at a time, and any difference between the operation of the two pairs or between members of each pair will be apparent.

Q. What is the firing order of the Ford motor?

A. 1-2-4-3.

Q. How are the coil vibrators adjusted?

A. The usual method is to turn the adjusting screw up until the vibrator stops buzzing; then turn the screw down again very slowly until the points just come together and the firing of that cylinder becomes regular; then give the screw an extra quarter-turn down, and lock in place.

In adjusting K-W coils, it is important to see that the little flat-cushion spring just underneath the vibrator bridge works back and forth every time the points make and break contact. This can be determined by taking the coil unit out of the box and holding the vibrator up to the light; press down the vibrator and observe the action of the cushion spring. It is important to adjust all the units alike or the motor will not develop its full power.

Q. What is the effect of adjusting so that the contact points are too far apart; too close together?

A. If too far apart, the cylinder will not fire regularly or with its usual power. If too close together the current is likely to arc at the contact points, thus preventing the breaking of the circuit when the armature is drawn down, burning the points themselves, and sometimes putting the coil out of action entirely.

Q. Does the vibrator adjustment affect starting?

A. When the points are too close, more current is required to "make and break" the contact between them, and the motor must be turned over that much faster. For the best adjustment, the points should barely touch. If the adjustment is too light, they may not do this and a miss at that cylinder will result.

Q. If the vibrator buzzes constantly, what is the trouble?

A. There may be a short-circuit at the timer or in the wire leading from that coil to it, or the coil itself may be defective. One of the first symptoms of a defective coil is the buzzing of the vibrator, with no spark at the plug.

Q. How can a defective coil be determined?

A. To make certain that the cause is in the coil, change the location of the units in the coil box. If another unit acts the same when substituted for the one giving trouble, the fault is not in the coil but in some other part of the system. Should the coil that is shifted, however, act the same in its new location, and the one that takes its place operates properly, the coil itself causes the trouble.

Q. When there is an unusually heavy or "fat" bluish spark at the contact points, what is the cause?

A. The current may be arcing at the points, due to their being adjusted too closely; or the condenser may have broken down. To make certain that the condenser has failed, disconnect the secondary cable from the spark plug and hold the terminal about $\frac{1}{32}$ inch away from the metal end of the plug. If the condenser has failed, the spark occurring at this gap will be irregular.

Q. What will happen if the contact points are allowed to become pitted and ragged, due to the burning effect of the current?

A. They are liable to stick together and cause unnecessary difficulty in starting or occasional missing when running. They should be trued up with a very fine flat file or with an old piece of fine sandpaper. Never use emery.

Q. When the vibrator points burn badly in a very short time, what is the cause?

A. The owner of the car has probably replaced the original vibrators with cheaper substitutes having nickel or German-silver contact points. Nothing but platinum or platinum-iridium contacts will give satisfactory service, so that new parts from the makers should be installed.

Q. When the engine will suddenly lag and pound, what is the cause?

A. An intermittent short-circuit in the wiring or at the commutator. The pounding is caused by the premature explosion of the charge against the rising piston. The vibration causes the short-circuit to occur at some times, and not at others, so that the engine will run regularly for a few minutes and then pound again, until the movement once more temporarily eliminates the cause.

Q. With all the vibrators properly adjusted and the timer and wiring in good condition, what is the cause of irregular firing?

A. Provided the spark plugs are all in good condition, points not too far apart, etc., this is frequently caused by the top of the coil box coming loose. The coil units are provided with brass-strap terminals on the bottom of the wooden casing of the coil, and these terminals make contact with similar straps in the bottom of the coil box on the dash. They depend for good contact on the pressure exerted by the cover of the box, which must always be kept tightly snapped on.

Q. When missing is not traceable to any of these causes, what is likely to be the cause?

A. Something outside of the ignition system, such as a weak-valve spring, or a valve improperly seating, due to some other cause. Loss of compression at the cylinder-head gasket: run a little lubricating oil along the edge of the gasket and note whether bubbles appear. Replace with a new gasket if any leakage is apparent.

Magneto

Q. How does the Ford magneto differ from the regulation type?

A. The *magnets* are revolved instead of the *armature;* it has sixteen field poles and armature coils, and it revolves at crankshaft speed to fire a four-cylinder motor. It is not timed to the motor the same as an ordinary magneto, which is coupled to the camshaft, or other half-time shaft, and the distributor of which must rotate synchronously with the motor.

Q. Of what does it consist?

A. Two discs, one carrying sixteen magnets with their poles pointing outward, and the other sixteen coils of strap copper on oval cores, all of the coils being connected in series. The disc carrying the magnets is rotated by the flywheel to which it is attached, while the other disc is attached to the crankcase, and remains stationary. One end of the coil winding of the magneto is grounded on the supporting disc carrying the coils, while the other is led to a terminal which extends through the flywheel housing. A cable from this terminal or binding post, supplies current to the coils.

Q. Is it ever necessary to remagnetize the magnets of the field, and how can it be done?

A. Unless they have become demagnetized, due to some outside influence, it is rarely necessary to touch the magnets.

Q. How can they become demagnetized by an outside force?

A. The attachment, by mistake, of a storage battery to the magneto terminal will send a current through the coil windings in the opposite direction, and will demagnetize them. When this happens, it is not advisable to attempt to remagnetize the old magnets, as it is much cheaper and quicker to replace them. The new set is supplied mounted on a board in exactly the position they should be installed.

Q. How can the magneto be dismounted?

A. To do this, it is necessary to remove the power plant from the car. The radiator must be taken off by disconnecting its stay rod and taking out the two holding bolts at the frame, after uncoupling the hose connections. Remove the dash and loosen the steering-post bracket, fastened to the frame, permitting the dash and steering gear to be lifted off as a unit (wires having first been disconnected); take out bolts, holding front radius rod in socket underneath the crankcase; remove four bolts at the universal joint; remove pans on either side of cylinder casting; disconnect feed pipe from carburetor, and exhaust manifold from exhaust pipe, by unscrewing large brass nut; remove the bolts which hold the crankcase arms to the frame at the side; then pass a rope through the opening between the two middle cylinders, and tie it in a loose knot; through the rope pass a 2 by 4 timber or a heavy iron pipe about ten feet long; with a man at each end of this and a third at the starting crank, the whole power plant can readily be lifted out; then remove the crankcase and transmission cover, and take out the four cap screws that hold the flywheel to the crankshaft. This gives access to every part of the magneto mechanism. To take out the old magnets, simply remove the cap screw and bronze screw which holds each in place. When reassembling the magneto, great care must be taken to see that the disc or plate carrying the magnetos revolves them exactly $\frac{1}{32}$ inch of the core faces of the coils.

Q. How can it be determined whether the magnets are at fault or not?

A. Whenever there is a partial failure of the current, remove the binding post by taking out the three screws which hold it in place. Clean out any dirt or foreign matter that may have accumulated under the contact spring. If this does not materially improve the running, test by comparing with battery ignition. Connect one terminal of a six-volt storage battery to the battery terminal on the coil box (a battery of four or five fresh dry cells will serve equally well for a short test run), and ground the other terminal of the battery on the frame of the car, making certain that good electrical connection is made. Run the engine at different speeds on the magneto, and, while running, throw the switch over suddenly to the battery point; any decided acceleration in the speed will indicate that the battery is supplying a much better current for ignition, and that the magneto is at fault. If used for any length of time for testing, a dry-cell battery will not give equally accurate results, as the cells are likely to run down very quickly, and the firing will then be better on the magneto, even though the latter be weak.

Q. When the engine suddenly fails to fire altogether, what is likely to be the cause?

A. The cable leading from the binding post on the magneto has dropped off, either at the latter or at the coil; or some piece of foreign matter has come between the contact spring attached to the binding post and its contact.

Q. When the magneto gradually gets weaker and weaker in a car that has seen a great deal of service, is it certain that the magnets have weakened?

A. Not necessarily; the adjustment of the bearings may be permitting the disc carrying the magnets to revolve further away from the armature coils than intended. Any increase in this distance, even though small, will have a decided effect on the output of the magneto.

GENERAL CAUSES OF IGNITION FAILURE

Q. When the motor stops very suddenly without any apparent cause, what is likely to be the cause of the trouble?

A. A break in the current-supply circuit of the ignition system, or sudden failure of the ignition current, due to any other cause.

Q. In how many different ways may this occur?

A. A feed wire from the battery may part from its terminal, either at the battery or at the coil; the ground wire may become disconnected at either end; in a dual system, the primary cable from the magneto to the coil may become disconnected, either at the magneto or at the coil; the secondary cable from the coil to the magneto distributor may loosen and drop off, either at the coil or at the magneto; this secondary cable may become grounded between the coil and the magneto; the switch may have loosened up, through vibration, and may jar open; the magneto may have become grounded internally, so that no current is delivered to the outside circuit. The magneto cam may have loosened up on its shaft, so that it no longer revolves with the latter, and, consequently, does not open the contact points in the breaker box. The primary cable from the magneto to the coil may have become grounded on the frame or short-circuited on another cable, due to wear from chafing, thus preventing the current from reaching the coil. In a dual system, the entire system may have become grounded through the metal of the dry cells coming in contact with the metal battery box or other metal part connected to the chassis of the car.

Q. Do the foregoing constitute all of the possible causes for a sudden failure of the ignition system?

A. No brief résumé could possibly include all of the causes that may exist for a stoppage of this kind, but they include probably more than 90 per cent of all the commoner causes of such a failure, and, either as given above, or in some modified form of the same condition, will be found to represent by far the greater part of all the causes of sudden stoppage.

Q. Of the causes given above, which are the most likely, in the order of their usual occurrence?

A. The loosening of a battery connection at the terminal or at the coil, or of a magneto and coil connection at either end; grounding or short-circuiting of either the primary or secondary main connection between magneto and coil, that of the secondary being more frequent owing to the high-tension current it carries. Grounding of the dry cells in the battery box; loosening of the switch so that it jars open. With the exception of the grounding of the primary or secondary cable between the magneto and the coil, all of the above are the direct result of vibration and jarring. In old four-cylinder motors, vibration is constant, and at times very severe, so that attention should first be directed to searching for loose connections, as unless tightened up at intervals, they are very likely to shake off. Internal grounding of the magneto or loosening of the breaker-box cam, so that the interrupter does not operate; these are rarer causes of trouble, and a search for them should be deferred until after the commoner causes mentioned above have been thoroughly investigated.

Q. Where all connections have been tightened up without overcoming the trouble, how can the other possible causes of stoppage be eliminated, in tracing the real seat of the failure to run?

A. See that the dry batteries of a dual system are not touching any metal; inspect the magneto breaker box while another person slowly turns the motor over by hand, so that the operation of the interrupter may be noted. If working properly, disconnect the secondary cable from the magneto to the coil, and with the motor running, hold its terminal $\frac{1}{4}$ inch away from the coil connection. In case there is no fault here, a bright spark will result at the gap. Note whether holding the cable away from the motor has been responsible and whether, when it is dropped back on the motor again, sparking occurs at any point along its length between the cable and the metal of the motor. Disconnect the primary cable from the magneto to the coil, and, with the motor running, wipe its end on the primary terminal of the coil; sparking should result if there is no break in the cable. Take the same precaution in putting it back as with the secondary cable to see that it is not grounding at some place along its length where it touches the motor. No visible spark will be produced in this case, but the condition of the insulation of the cable itself should be the best indication of this kind. Bend the wire along its length to detect any possible breaks in the copper wire under the insulation. Disconnect the ground cable from the coil to the magneto, and, while the motor is running, hold it close to either the magneto or the coil terminal; a high-tension spark will result if the cable is all right. Note, while the motor is running, whether there is any sparking at the safety gap, on the magneto itself, if on the high-tension type, or on the coil of a dual system. Note whether the primary and secondary cables cross each other, and whether there is any sparking between the two while the motor is running. Inspect the ends of all stranded cables carefully, and see whether one or more of the fine wires have not broken through the insulation and become bent over, so as to ground the cable on some adjacent metal.

Q. Is a sudden stoppage of the motor likely to be due to any cause other than a failure of the ignition system?

A. One possible cause is the sudden and complete stoppage of the carburetor spray nozzle, but, even in this case, the failure of the motor will not be so sudden nor so complete as where the ignition current has been cut off, as the motor will continue to fire, for a few revolutions on what fuel mixture remains in the manifold. There is practically no other cause for the motor suddenly stopping.

Q. When, instead of stopping completely, the motor will fire regularly for a few minutes, hitting on all cylinders, and then begins to miss spasmodically, how can it be determined whether the fuel-supply system or the ignition is at fault?

A. The fact that, under such circumstances, the motor will fire regularly for a little while and then miss very badly, and, a few minutes later again take up its operation smoothly, is usually an indication that the ignition system is working properly, but that at intervals there is a failure of the fuel supply. One of the commonest causes of this is the exhaustion of the main supply of gasoline in the tank. On the last half-gallon or so of fuel there is no longer a regular supply to the carburetor, with the result that, with the motor running at speed, what gasoline is in the carburetor is practically exhausted in a few minutes. During this period, however, the motor will continue to run regularly. As it lowers the level in the carburetor float chamber, an insufficient supply is drawn through the nozzle and the motor misses badly, and slows down almost to the stopping point. This permits a new supply to fill the carburetor, and the motor once more runs properly. It is the extremely intermittent nature of the firing, with first one cylinder missing and then another while the carburetor is refilling itself from what little gasoline remains in the tank, that makes this appear very much as if it were due to failure of the ignition. Under conditions such as this, always inspect the fuel supply first. With an ample supply of gasoline in the tank, a partial clogging of the spray nozzle of the carburetor, due to some obstructions which is intermittently drawn up into it by the suction and again drops back, will give exactly the same symptoms of ignition trouble.

Q. Are symptoms of this nature ever due to a fault in the ignition system?

A. They will result at times from the use of a set of dry cells that is almost exhausted. The storage battery also acts in a similar manner. Both the dry cell and the storage battery recuperate very rapidly even when practically exhausted, so that they will often provide sufficient current to run the motor properly for a very short time, will then cause it to miss badly, and shortly afterward again run regularly. If, when the switch is thrown over to the magneto, the motor runs smoothly and continuously, there is no doublt that the battery is at fault, and this may be verified by testing the cells with a pocket ammeter. Should they show much less than eight amperes on test, they are the cause of the trouble and should be discarded. This may also be due to the use of a storage battery that is practically exhausted, though it would be extremely bad practice to allow a storage battery to get this low. Test with the voltmeter: if the cells show 1½ volts each or less they are badly in need of charging, and if they will not run the motor properly, should be immediately recharged from an outside source of current.

Q. What is meant by "pre-ignition", and what causes it?

A. When the charge in the cylinder is ignited before the passing of the spark at the spark plug, it is said to be "pre-ignited", i.e., fired in advance of the proper time. As a result, the force of the explosion is partly exerted against the rising piston, as is evidenced by a heavy pounding accompanied by a decrease in the power. The cause is usually an accumulation of carbon in the form of a deposit on the piston head and results from excessive lubrication. The surplus oil finds its way into the combustion chamber and is burned. This condition is further aggravated by running with an over-rich mixture. If the motor is allowed to run very hot, these carbon deposits become incandescent, so that the fresh mixture is fired the moment it comes in contact with them. In some cases this becomes so bad that the motor cannot be stopped without shutting off the gasoline supply.

Q. How can the pounding caused by pre-ignition be distinguished from other internal noises, such as those produced by a loose crankshaft or crankpin bearing?

A. Pre-ignition takes place only after the motor has been running long enough to become very warm and with the throttle opened to any extent the pounding is very violent, jarring the whole chassis. The noise produced is distinctive and can be identified readily once it has been experienced. Unless very loose, a bearing noise will practically disappear if the motor is allowed to idle very slowly and will always increase in proportion to the load, becoming very severe when climbing a hill.

Q. How can the condition which causes it be remedied?

A. By removing the carbon deposits. In many late-model engines this can be done most readily by removing the cylinder heads, usually a single casting. The carbon may be burned out with the oxygen-gas flame now in common use or it may be loosened by the use of kerosene in the motor. After the motor has run long enough to become hot, shut off the gasoline supply gradually, meanwhile feeding kerosene through the auxiliary-air inlet of the carburetor until the motor is running on kerosene alone; feed an excess of the latter and the carbon will be loosened and blown out through the exhaust.

Q. When a single cylinder continues to miss regularly, all the others running properly, and inspection shows every part of the ignition system to be in good condition, what is likely to be the cause?

A. Failure of its valves to operate properly. Either the inlet or the exhaust valve is not opening, or is sticking open (the result will be the same in either case). This may be caused by a weak valve spring, a bent valve stem, derangement of the valve tapper, so that it does not strike the valve-stem end, or by a piece of foreign matter, such as a piece of carbon, lodging on the seat of the valve, so that the latter cannot close. Another, though rarer cause, is a leak in the manifold, close to the inlet valve of the cylinder in question. This permits an excessive amount of air to be drawn into that particular cylinder, so that the charge is too weak to fire. In any of the above cases, the result is that fuel either does not get into the cylinder or it is exhausted before it can be fired, as with every part of the ignition system working properly, the only thing that can cause a cylinder to miss is lack of fuel.

Q. Mention one of the causes of irregular firing that is seldom suspected, except by those who have experienced it previously?

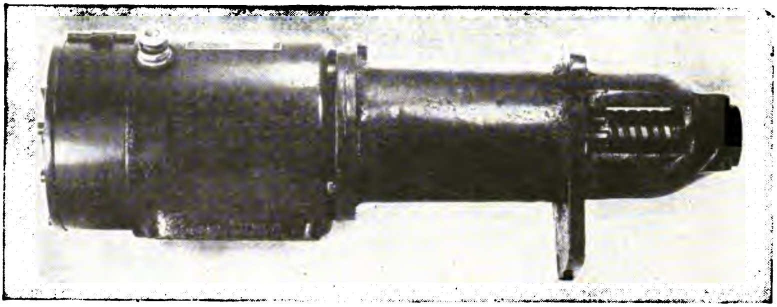
A. Excess oil finding its way into the combustion chambers in such quantities that it covers the spark-plug electrodes, thus preventing a spark from jumping the gap. The oil, particularly when fresh, is an excellent insulator and, if mixed with carbon so that it conducts the high-tension current, it does so without permitting the formation of a spark. Owing to the viscosity of heavy lubricating oil, it clings to the spark-plug points and when they are as close together as they should be ($\frac{1}{32}$ inch), it will often bridge the gap for some time, despite the vibration and succeeding compressions in the cylinder. This fault is particularly difficult to locate when not suspected, as jolting over a rough piece of road will shake the plug points free and the engine will fire regularly, again missing intermittently when on smooth going once more. When confined to one cylinder, it is usually an indication that the cylinder wall is scored, or that the lubricating-oil feed to that cylinder is deranged.

Q. Mention a rare cause of what appears to be ignition failure?

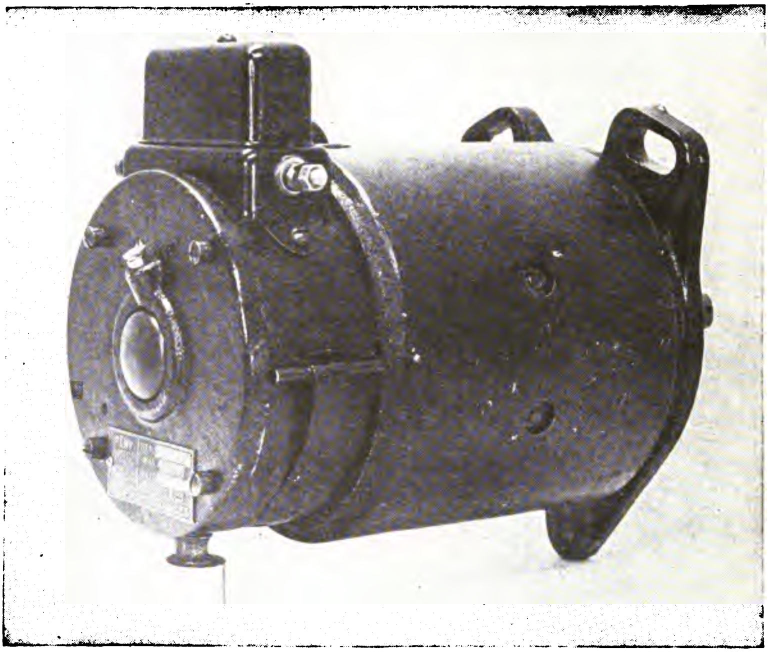
A. When a motor has been taken down and all its working parts thoroughly cleaned with gasoline or kerosene, it will sometimes be found next to impossible to start it. The explosions are very weak and erratic, and the engine does not generate sufficient power to run more than a few revolutions at a time. The trouble has every indication of being due to a derangement of the ignition system and looks particularly as if it might be faulty timing, caused by misplacing the spark-plug leads. In one case of this kind experienced by the writer, all the spark plugs and wiring were renewed, fresh batteries put in, and every part of the ignition system checked by three experienced garage men, but the motor could not be made to run. The trouble was finally overcome by taking out the spark plugs and injecting two or three ounces of the heaviest cylinder oil into the combustion chambers. The motor was old and well-worn so that the pistons were loose; the cleaning process left all these parts wet with kerosene and there was enough of the latter left in the crankcase to thin out the fresh lubricating oil considerably. As a result there was no compression, and the force developed by the explosion was not sufficient to turn the motor over for more than a few revolutions; what little oil was splashed up by this was too thin to seal the space between the pistons and cylinders so that most of the power generated by the weak explosions leaked past the pistons. Trouble of this nature is most likely to occur in old and well-worn motors, and will sometimes result from excessive priming with gasoline, i.e., squirting gasoline in through the petcocks or spark-plug holes, as this washes all the lubricating oil from the cylinder walls into the crankcase and thins the oil in the latter.

Q. When intermittent failure of the ignition is thought to be due to faults in the wiring which cannot be detected by an ordinary examination, how can the trouble be found most readily?

A. Fit a handy length of cable—one that will span practically any two points in the ignition system—with spring-clip terminals. Disconnect each wire in turn, and substitute for it this length of cable as a temporary connection; satisfactory operation with the latter indicates that the wire it replaces is at fault.



TYPICAL REMY STARTING MOTOR
Courtesy of Remy Electric Company, Anderson, Indiana



TYPICAL GENERATOR FOR REMY STARTING AND LIGHTING SYSTEM
Courtesy of Remy Electric Company, Anderson, Indiana

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART IV

ELECTRIC STARTING AND LIGHTING SYSTEMS

GENERAL FEATURES

Fundamental Characteristics. In the introduction to elementary electric principles, no attempt has been made to go beyond simple theory as applied to the generation of electric currents, the operation of electric motors, circuits and the auxiliary devices required by the lighting and starting systems employed on the automobile. A very large part of the theory of electricity and electrical action as given in the majority of textbooks is omitted altogether for the sake of clearness, only that part of it which bears directly on the subject of electrical equipment of the automobile being retained. In the presentation of the latter, a somewhat different method of handling the subject has been followed, particularly with a view to making it appeal to the practical man by citing examples and comparisons, the force of which is at once clear. The man whose time for study is limited has no opportunity to go into all branches of electrical phenomena, so that the subject is presented in the briefest and most practical manner.

Considering that the practical application of electric lighting on the automobile dates back to 1910 only and electric starting to 1912 models, in which year but one make of car was fitted with a complete system as regular equipment, there are a number of different types in use. Each is characterized by varying features of design in the generators, motors, and auxiliary devices. In many instances these are slight, in others they are radical, but in every case they merely represent a different application of the fundamental principles given in the introduction. Since they must first pass the test of practical use before being adopted by the automobile manufacturer, they all operate successfully. But, that they all do not operate equally well, or, to put it better, all do not continue to shew the same high degree of efficiency and reliability in service, goes without saying. Owing to the lack of standardization that prevails, it is necessary to become familiar with each system. A brief analysis of each of the systems in general use accordingly is given here, and it will be found valuable for reference.

VARIATIONS OF OPERATING UNITS AND WIRING PLANS

Principal Differences. Before taking up the different systems in detail, an outline of the chief points on which they vary is given as an aid in distinguishing them when found in service on the various makes of automobiles of which they form a part. Electrical systems as a whole may be divided into two general classes. These are the single-unit and the two-unit types.

Single-Unit Type. The first type is characterized by the employment of a *dynamotor*—a single unit with generator and motor windings on the same armature and fields connected to independent commutators at each end of the armature, as in the Delco, (in some models, two concentric commutators at the same end) or to the same commutator, as in the Dyneto. The single-unit type is greatly in the minority, the two makes cited being the chief exponents of it, though both of them are also built in the double-unit type as well. When the ignition distributor is incorporated in the generator, as is now very generally the case, the single-unit types incorporate in one machine the three chief electrical functions required on the automobile, viz, charging the storage battery, turning the engine over to start, and distributing the ignition current.

Two-Unit Type. Owing to the difficulty of efficiently combining in one machine two functions so widely separated as the generation of a constant charging current of a value rarely exceeding 20 amperes, and the utilization of currents up to 350 amperes, such as are required for starting, the majority of systems are of the two-unit type. The latter also is generally favored owing to its greater convenience of installation, as the dynamo must run either at motor speed, or at 1½ times that, while it is necessary to gear the starting motor to the engine in the ratio of 30 or 40 to 1. As the term implies, an independent unit is employed for keeping the storage battery charged, lighting the lamps (when running), and distributing the ignition current, while a second unit is installed solely for the purpose of turning the gasoline engine over to start.

Single-Wire and Two-Wire Systems. The difference between these is pointed out in detail in the section on Wiring Diagrams, Part IV. Owing to its greater simplicity of installation, reduced cost for wiring, and the greater ease with which faults may be located, the single-wire system is largely in the majority. In fact, there are only one or two examples of two-wire systems in general use, of which the Bijur, as employed on the Packard, Jeffery, and other cars, may be cited as an instance. In the gradual approach to standardization that is being made each year, the number of cars on which the single-wire system is employed is constantly increasing. But differences will be found in these single-wire systems as well, some employing the frame of the car for the positive side of the circuit, and others for the negative. This must be borne in mind when testing for faults with the volt-ammeter.

Comparison of Systems. While inherently more dangerous, experience has demonstrated that the fire hazard with the single-wire system is more a matter of proper installation than of the comparative merits of the systems themselves, and quite a number of manufacturers who adopted the two-wire system at the outset have later become converts to the single-wire system. In fact, while the Society of Automobile Engineers has not adopted the latter as recommended practice up to the present writing, although the subject has been under investigation for almost three years, the majority of automobile makers have taken it as their standard construction, and it seems more than likely that the others will do so before long. Considerations of economy demand this on the lower-priced machines, as the cables employed are so expensive as to make a substantial difference in the cost per car for the electrical equipment where the single-wire standard is employed. It does not follow from this that where the maximum of safety and efficiency are to be attained regardless of cost, the two-wire system is always employed, as, after experiencing considerable difficulty with it, the makers of the Pierce-Arrow adopted the single-wire system. The Packard, on the other hand, employs the double-wire system, and the advantages in simplicity of the single-wire may be noted by comparing the Packard installation, as shown in Fig. 144, with the Delco single-wire system, Fig. 145, which is employed on a great number of cars. Comparison cannot be made exactly on the same basis in these two installations, however, as the Packard is what is known as a two-unit system, i.e., the generator and the electric starting-motor are independent, while the Delco is a com-

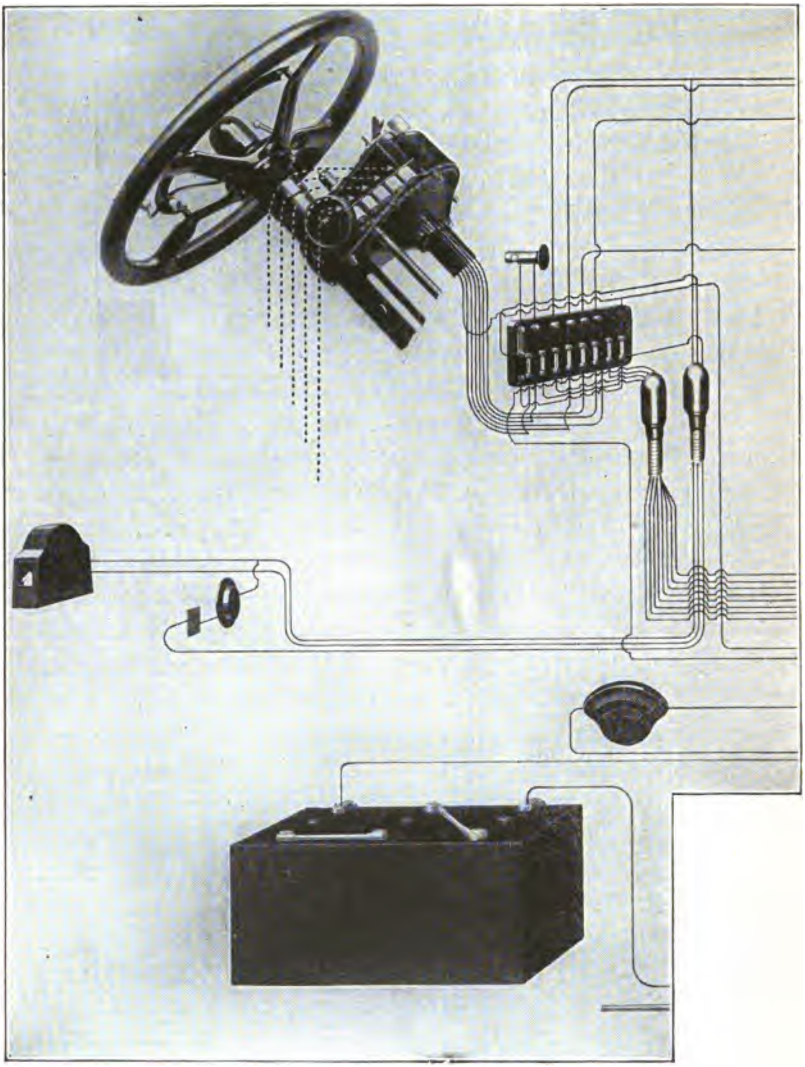
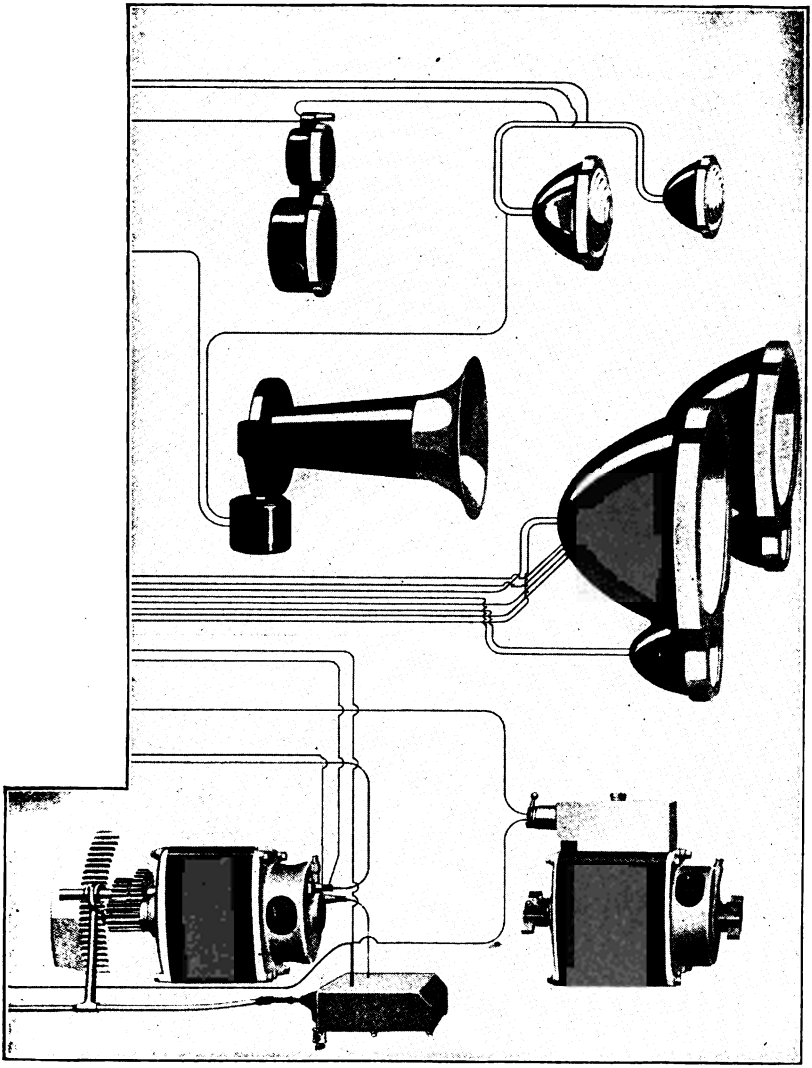


Fig. 144. Wiring of Packard (Bijur) Two-Unit, *Courtesy of Packard Motor Car*

bination generator, motor, and ignition unit. Moreover, the Packard has several additional lamps, being fitted with double bulb



Two-Wire Starting and Lighting System (1916 Model, Six-Cylinder)
Company, Detroit, Michigan

headlights and side lights, which are not present in the Delco installation; but even omitting these considerations, it will be seen that the single-wire system has the advantage of simplicity in a marked degree.

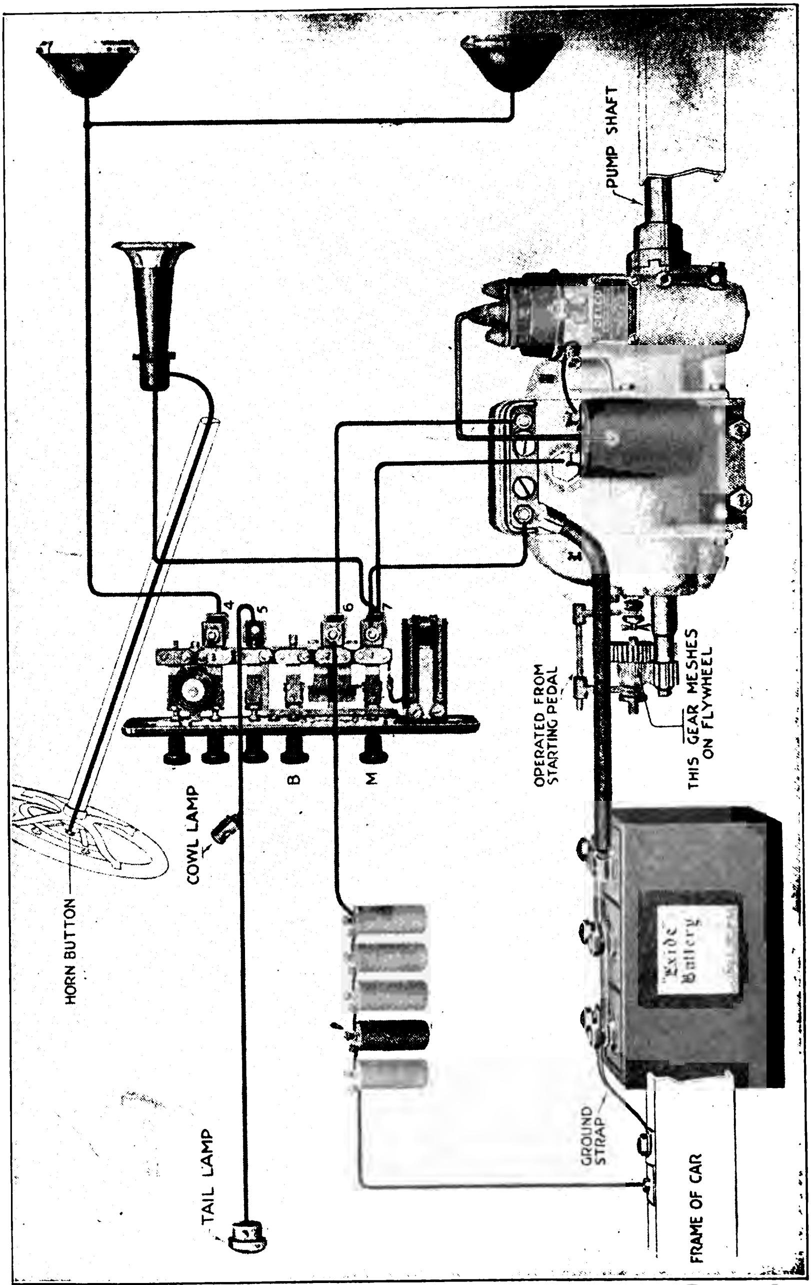


Fig. 145. Wiring of Delco Single-Unit, Single-Wire System
Courtesy of Dayton Electric Laboratories, Inc., Dayton, Ohio

METHODS OF REGULATION

Necessity for Control of Generator Output. In the section on Generator Principles, Part I, mention has been made of the fact that the speed with which the armature coils cut the lines of force of the magnetic field is the chief factor determining the e.m.f. and, in consequence, the current output of the generator. This, in connection with the heating effect of the current due to the resistance of the conductor, limits the amperage that the latter will carry safely. Beyond this point the insulation will take fire and, with a further increase in the temperature due to excessive current, the conductors themselves will fuse. With the extreme variation in speed presented by the operation of the automobile engine, the necessity for regulating the output of the generator will be apparent. There are almost as many methods of regulation as there are systems in use.

As explained in the section on Induction Sources of Ignition Current, Part II, the magneto is an electric generator that requires no current-controlling device, as the magnetic excitation of its fields is permanent. That is, barring gradual exhaustion through age, heat, and vibration, its magnetic field is constant, thus enabling it to generate a current at very low speeds; but the limitations of this type of field are such that electromagnetic fields are employed as in large direct-current generators. These fields depend for their excitation upon the current derived from the armature of the machine itself, and, as the amount developed by the latter increases in direct proportion to its speed, the fields become stronger as the speed increases and correspondingly more current is generated by the armature. As an automobile motor is driven at a great range of speeds, varying from 200 or 300 r.p.m. up to 2000 to 2500 r.p.m., or even higher, and the generator is usually geared in the ratio 1:1½ so as to develop its rated output at the normal speed of the engine — its windings would be quickly burned out unless some provision were made to control its output.

Constant-Current Generator. Generators of the so-called constant-current type are frequently regulated by the winding alone. They are usually compound-wound, the series coil being so connected as to oppose the shunt. Assuming the coils to be in equally advantageous positions on the core, the limiting current then is one which gives the same number of ampere turns to the series coil as to the shunt field. Thus, assuming 500 shunt turns in the winding and a shunt current of one ampere, there are 500 ampere turns in the shunt winding. If there are 25 turns in the series winding, the limiting current will be 20 amperes, 500 being the product of 20 by 25. With this winding 20 amperes will be the absolute limit of the current regardless of speed. As a matter of fact, it will be considerably lower than this in practice, owing to the armature reaction or counter e.m.f. generated.

Slipping-Clutch Type. As in every case speed is the direct cause of a rise in the voltage or increase in the current output, one of the methods available for regulating generators is that of mechanically governing the speed at which the generator runs. In the Gray and Davis, which is probably the most important representative of this type, a slipping clutch is used for this purpose. A centrifugal governor is employed, as shown in the sectional view, Fig. 146. The drive is through a two-plate friction clutch at the left, the plates of this clutch being normally held in engagement by a spring. The tension of this spring is controlled by the centrifugal governor to which it is attached at the right-hand end, and it may be adjusted to compensate for wear by means of the threaded shaft and nut. This clutch is set to slip at a certain torque and, as soon as the current value corresponding to this torque is attained, the clutch lets go, and the current cannot exceed this limit. Accordingly, one plate of the clutch (the driving side) runs faster than the driven side in proportion to the difference in the speed of the gasoline engine

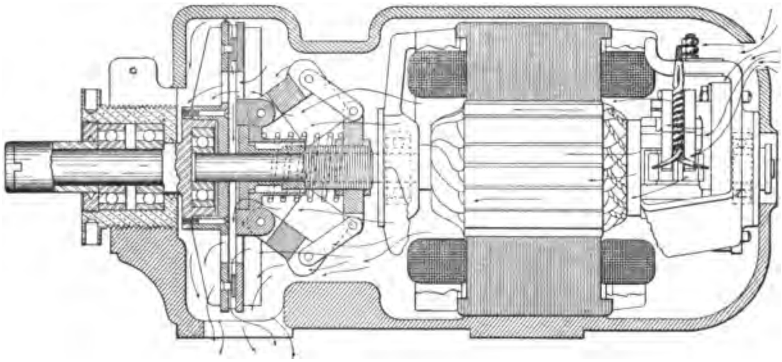


Fig. 146. Section of Gray and Davis Lighting Dynamo (Early Model, Now Obsolete)

and that at which the generator is designed to run, the *torque* on both sides of the clutch remaining the same regardless of this difference. Ventilation is provided to carry off the heat produced by the slipping clutch, the opening and the arrows shown in the illustration indicating the direction in which air is drawn into and expelled from

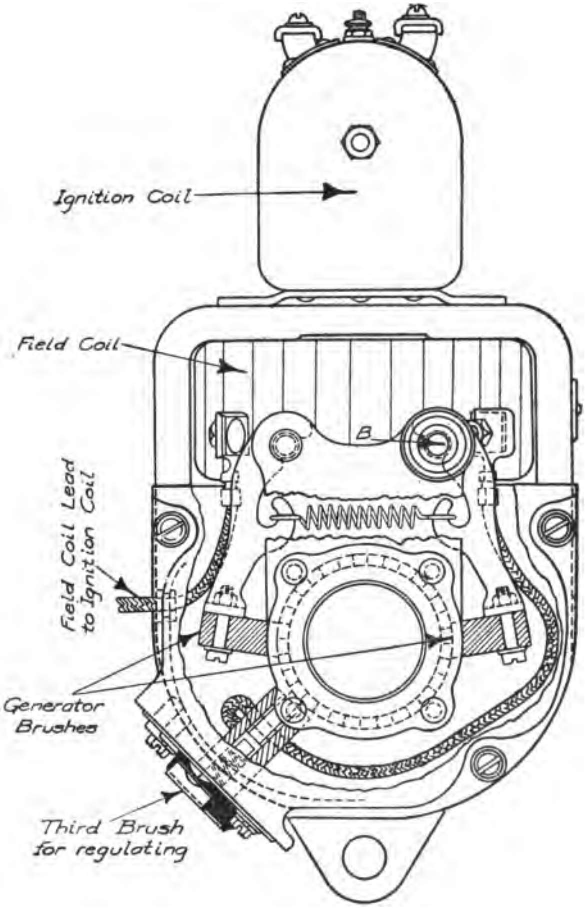


Fig. 147. Delco Third-Brush Method of Regulation

the housing. The generator is of the compound-wound type, and is known as a constant-speed constant-current dynamo. Regulation in this case is by purely mechanical means.

Inherently Controlled Generator. *Westinghouse Type.* A typical example of inherent regulation is represented by the Westinghouse generator. (See Fig. 116, Part III.) When the generator is connected to the battery by the automatic cut-out, the current rises rapidly with the speed until a moderate value is attained. Current in excess of this value passes through a compound series winding, the polarity of which is opposite to that of the shunt winding of the fields. Consequently it acts to oppose the excitation set up in the field magnets by the latter above a certain point. This is known as a "bucking coil" and, while it permits the value of the current generated to increase slightly over the predetermined limit with a further increase in speed, it does not allow it to reach an excessive amount at any speed at which the car can be run. However, current for the lights does not pass through this reversed compound field winding and, when the lights are turned on, the output of the generator increases automatically to supply them. With the usual lamp equipment, this increase in generator capacity is sufficient to operate the lamps without any demand on the battery at ordinary running speeds. At low speeds the battery supplies a certain proportion of the lighting current, and when the engine is not running the battery takes care of the entire demand. When running at night, all current in excess of that required by the lights is utilized to charge the battery, which is thus said to "float" on the line. During the daytime, the entire output of the generator is absorbed in charging the battery.

Delco Third-brush Excitation. Another form of inherent regulation consists of the use of a special brush for taking the current from the armature for the purpose of exciting the field. An instance of this is found in the Delco two-unit system as built for the Oakland cars (1916 models). As the generator is a bipolar type, there are only two brushes for leading the current from the armature to the external circuit, so that the special regulating brush employed, as illustrated in Fig. 147, is commonly referred to as a "third brush". This applies only to this particular type, however, for if the generator were a multipolar type having four brushes, the regulating brush would then be a *fifth* brush. The Delco generator is shunt wound but differs from the standard machine of that type in that the shunt winding is connected to the third brush which bears on the commutator between the other brushes. This method has the advantage of providing a strong shunt field at low speeds so that the generator commences charging while the car is still traveling at a very moderate pace. As the speed increases the voltage applied to the shunt field is decreased, although the total voltage between the main brushes may have increased. This weakens the field and prevents the output of the generator from increasing with the increased speed. At the higher speeds it acts somewhat similarly to the bucking coil previously described, in that it still further weakens the field and causes the generator output to decrease.

Bosch-Rushmore Type. In the Bosch-Rushmore generator, inherent regulation is obtained with a bucking-coil winding used in conjunction with a so-called "ballast" coil, which automatically cuts the bucking coil in or out of the circuit according to its resistance, Fig. 148. Advantage is taken of the fact that the electrical resistance of iron increases enormously after its temperature rises beyond a certain point. This ballast coil accordingly consists of a few turns of fine iron wire on a fluted porcelain rod. The bucking coil, the effect of which is to reduce the field excitation of the dynamo, is connected as a shunt across the iron ballast coil, as shown in Fig. 148. Its resistance is considerably greater than that of the ballast coil when the latter is cold or only warm, so that at low engine speeds practically all of the current generated passes directly to the battery and lamps and the generator acts as a single-shunt dynamo. However, the resistance of the iron wire increases at a constant rate up to about 10 amperes, after which it mounts very suddenly, preventing the passage of any excess current, which, accordingly, must go through the bucking coil. Thus the latter only comes into action at high speeds, so that the output of the dynamo may be adjusted to any value within its capacity simply by employing an iron wire of suitable diameter in the ballast coil.

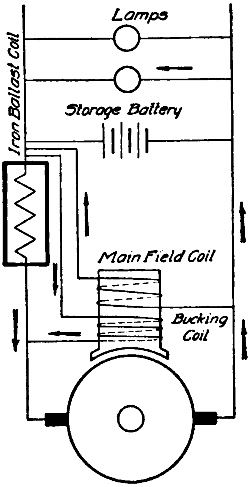


Fig. 148. Connections Bosch-Rushmore Generator

Independent Controllers. The Ward-Leonard controller (constant-current), Fig. 149, is typical of the external or independent controlling devices. In principle, this is the same as the Splitdorf and many others, the chief distinctions between the types usually being found in their construction. Referring to Fig. 149, the coil *F*, on the magnet core *G*, carries the armature current, and when the latter exceeds a certain value—the standard being generally about 10 amperes—the core becomes sufficiently magnetized to attract the finger *H*. This separates the contacts *EE'*, and the resistance *M* is inserted in the field circuit and weakens it. The current then decreases, but when it drops to about 9 amperes, the pull of the magnet is not sufficient to overcome the tension of the spring *J*, and the contacts *EE'* come together again. In actual operation, the finger *H* is kept vibrating at a rapid rate. As a result, the dynamo cannot charge the battery at a rate in excess of 10 amperes, regardless of the speed. At all car speeds above a predetermined limit, usually 15 miles per hour in practice, the dynamo generates a substantially constant current. The regulating device shown at the left of the figure is the automatic cut-out to break the circuit between the battery and the dynamo when the speed of the latter falls below a point at which it is no longer capable of producing the necessary voltage for charging. This is referred to later.

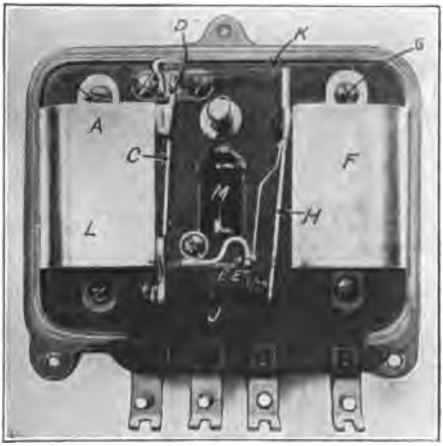


Fig. 149. Ward-Leonard Current Controller and Automatic Cut-Out

All external regulators are not of the constant-current type, however, as some limit the voltage.

Constant-Potential Generators. There is probably a greater variation in the methods employed to control this type than in the constant-current type. This difference is in the method rather than the principle employed, as the majority of such regulating devices act to control the potential by automatically inserting extra resistance in the field circuit or in series with the armature. Quite a number of generators of this type are fitted with a vibrating contact operated by a magnet in much the same manner as a vibrating ignition coil is actuated. The device is either built as a separate unit or is incorporated as in the Splitdorf earlier models.

"Built-In" Regulator Type. In the Splitdorf generator, where the armature is supported by the usual ball bearings, the field poles have extensions which carry windings for the purpose of aiding in the regulation. Extending across these polar projections is a "keeper" (an unwound armature) held by a spring, and in connection with this keeper is a second spring for adjusting the tension of the first spring. The circuit of the battery is closed by the keeper being drawn toward the pole tips under the influence of their magnetism when the machine is running. The coils around these polar extensions are wired in series with the armature of the generator. When the current in the armature reaches a certain predetermined value, the keeper is drawn all the way down and an auxiliary contact is opened which cuts a resistance into the shunt winding of the fields, and thus reduces the magnetic flux due to their action. This, together with the differential action of the series coils on the polar extensions, reduces the magnetic flux through the armature to such a value that the current to the battery does not increase beyond a certain value, no matter how fast the armature is turned. A sectional view of the machine illustrating the details mentioned is shown by Fig. 150. As the speed diminishes the reverse operation of the controller takes place. This generator is driven at twice the crankshaft speed of the motor, and when installed on a car with 34-inch wheels and geared at 3.7 to 1 on direct drive, begins to

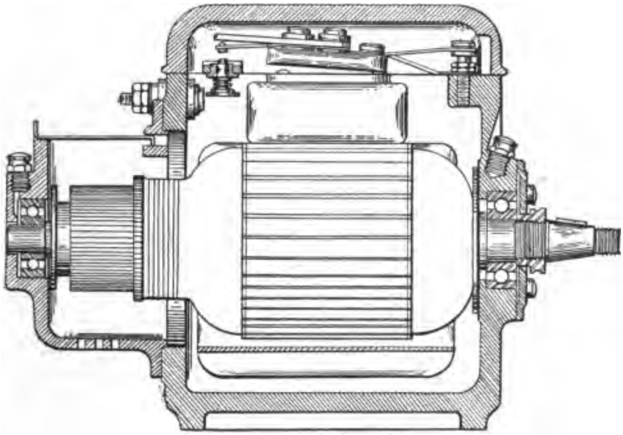


Fig. 150. Section of Splitdorf Generator Showing Controller

charge the battery at 7 miles per hour. The high-speed control acts when the car is running between 35 and 40 miles per hour.

External Regulator Type. The Adlake generator is of the constant-potential type governed by an external regulating device, the details of which are shown in Fig. 151. While termed a "regulator", it also incorporates the automatic battery cut-out and the fuses on the same base. This device has been in use on Pullman railroad cars for a number of years, the dynamo in that case being driven from one of the axles of the car. The principle is that of inserting added resistance in the field circuit of the dynamo as its output increases in order to maintain the voltage practically constant. Its operation is made clear by reference to the diagram, Fig. 152. *G* is a solenoid or hollow electromagnet, in the opening of which the plunger *K* may move vertically. The weight of *K* is counterbalanced by *N*, a small piston moving in the cylinder *O*, small shot being put in this piston until both are in equilibrium. They are connected by a chain passing over *M*. An arm *F*, attached to *M*, carries a movable contact designed to make connection with the various contacts of the rheostat *C*, thus putting in circuit a greater or less number of the German-silver-wire resistance coils composing it. These coils are connected in series with the field of the dynamo, which is a plain shunt-wound machine.

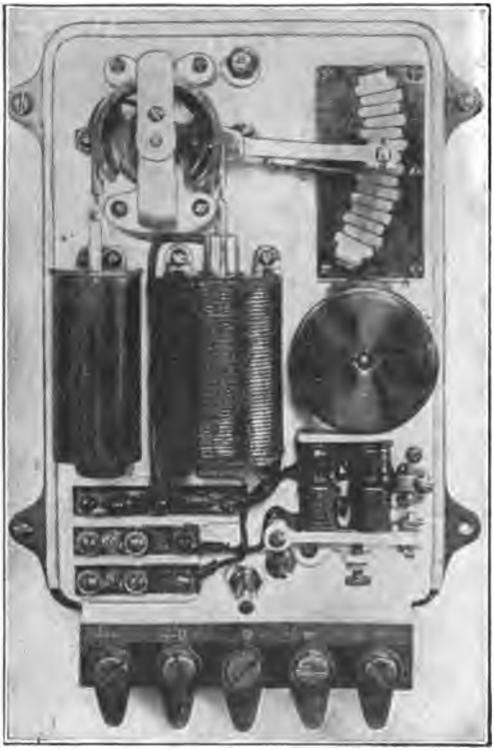


Fig. 151. Adlake "Regulator"

In explanation of the wiring diagram for the Adlake regulator, Fig. 152, start at terminal *A* of the generator; the current flows to A_1 on the regulator and thence to the fuse block *a*. It is here the shunt-field circuit begins. The field current flows from *a* through *b* to the rheostat terminal *c* and through a number of the sections of the latter, depending upon the position of the arm *F*, through this arm and back through *d* to the fuse block *e*, thence through the fuse to terminal C_1 and from there to the terminal *C* of the generator, thence through the two shunt-field coils and back to the negative terminal *B* of the generator. From *B* the current flows through the generator armature back to *A*, thus completing the circuit. There being only one field winding, the current always takes the same path, except that it has to flow through more or less of the resistance sections of the rheostat, of which there are fifteen. The path of the main or charging current is from the fuse block *a* to the connector

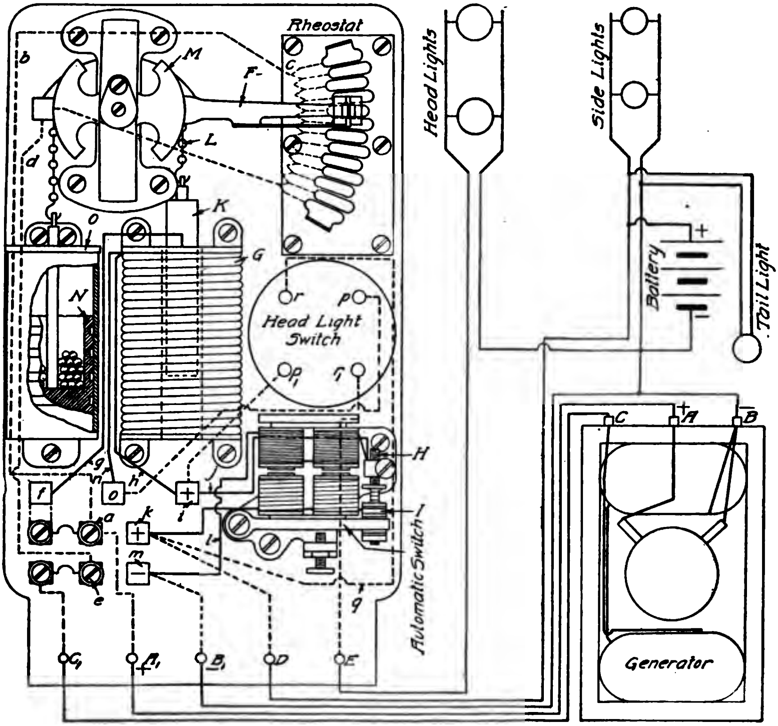


Fig. 152. Connections for Adlake "Regulator" (*Horseless Age*)

f, and through *g* into the solenoid coil *G*. It leaves this coil through *h* and flows to the contact block *i*, which connects by the wire *j* with the stationary contact screw *H* of the automatic battery switch. When the latter is closed for charging, the current flows across to the movable contact point *I* of the switch, and thence through the two lower or series coils of the automatic switch to the connector *K*. From this it flows to the terminal *D* of the regulator, which is directly connected with the positive terminal of the battery, and the current, after flowing through the battery, returns to the negative terminal *B* of the generator through connections clearly indicated.

There are a number of variations in the methods of regulation employed, as well as some that are not given in the foregoing résumé. These are explained in detail in connection with the descriptions of the different systems.

PROTECTIVE DEVICES

Various Forms. When fully charged, the storage battery holds in chemical form the equivalent of two or more horsepower, i.e., 40 to 160 amperes at 6, 12, or 24 volts, according to the system employed and the capacity of the battery furnished. An accidental ground or short circuit in the wiring system would release all of this energy in a flash to the great detriment of the battery itself as well as to any of the apparatus or parts of the car that happened to be included in its path or circuit. To guard against damage from such a cause, various forms of protective devices are employed, and the different systems vary as much in this respect as they do in others. In some instances, a circuit breaker is depended upon to take care of all the circuits. In others, further protection is afforded by the employment of fuses, as well as a circuit breaker. Fuses very generally are employed to protect the lighting circuits as well as some of the other circuits.

Automatic Battery Cut-Out. It will be evident that, if the storage battery were at all times in direct connection with the generator, it would immediately discharge through the latter as soon as the driving speed fell to a point where the dynamo was no longer producing sufficient voltage to charge the battery. If the generator were free to run instead of being positively connected to the engine, it would become "motorized" and operate as an electric motor on the battery current. As it is so connected, the battery current would simply burn out its windings, owing to the low resistance of the latter at low speeds. Consequently it is necessary to insert an automatic switch in the circuit in order to connect the battery with the generator when the speed of the latter reaches a certain point, and to disconnect it as soon as it falls below that value. Such switches are termed automatic cut-outs or "reverse-current relays." In single-unit systems, such as the Dyneto, no battery cut-out is employed. A single hand-operated switch controls both the ignition and the generator-battery circuits, so that this switch is left closed as long as the engine is running. Should the engine stall, the battery current automatically "motorizes" the generator and re-starts the engine. With such systems the engine must not idle slowly and the starting switch must not be left closed after the engine has stopped.

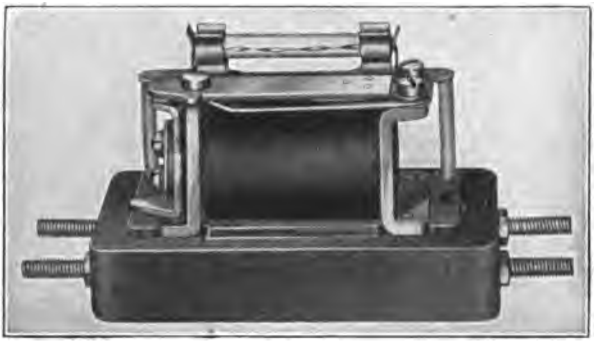


Fig. 153. Remy Reverse-Current Relay

Ward-Leonard Type. The Ward-Leonard, Fig. 149, is typical in that it clearly illustrates the principles upon which most of these devices are based, though their construction varies widely, as will be noted by Fig. 153. The switch mechanism is shown at the left of Fig. 149. In this device *A* is the coil, *B* the magnet core, *C* the movable arm, and *DD′* the contacts. The dynamo generates sufficient voltage at a car speed of approximately 7 miles per hour to attract *C* and hold it in position, closing the battery circuit through *DD′* and charging at any speed above starting speed.

Adlake Type. In Fig. 151, the automatic cut-out switch is seen at the lower right-hand corner of the panel. This differs from the usual types in that it has two shunt and two series electromagnets.

The closing of the switch is effected by the two upper or shunt coils. The current for these coils follows the path of the main charging current as far as the stationary contact screw *H* of the switch, from which a connection leads to the fine windings of the shunt coils; after passing through these coils, it flows through the wire *l* to the connector *m*, which is connected to the terminal B_1. Consequently, as soon as the generator begins to pick up, current flows through the two upper or shunt coils of the switch, and when the magnetism due to this current becomes strong enough the switch closes. Current then flows into the battery for charging, first passing through the two lower or series coils, which greatly increase the pressure at the contact points as long as the charging current is flowing, and insuring a positive interruption of the current when the generator voltage drops below that of the battery. A powerful actuating force is thus obtained with very small magnets.

Circuit Breaker. Circuit breaker, as employed in this connection, must not be confused with "battery cut-out". The cut-out is literally a circuit breaker and is referred to as such by some manufacturers in their instructions, but in electric terminology, as employed in everyday use, the circuit breaker and the cut-out are entirely different things. A circuit breaker is designed to operate only when a current considerably in excess of that for which its circuit is intended passes through it. Whether a protective device is a cut-out or a circuit breaker may be determined by the circuit in which it is placed. The cut-out is never employed in any other circuit than that of the generator and battery. A detailed explanation of the circuit breaker is given in connection with the Delco system.

STANDARDIZATION

Voltage Standards. Weight reduction is a problem of the greatest importance on the automobile and as energy in the form of a lead-plate storage battery is very heavy, the size of the latter is very closely limited. Power, however, depends not so much upon the amount of energy available as it does upon the pressure at which it can be applied. Thus, by doubling the voltage of a storage battery, the capacity needed can be reduced correspondingly. Where only three cells are employed, they must be very much larger than when six are used, and the cells of the latter must be correspondingly larger than those of a 9-cell or a 12-cell battery. While there are a few adherents of the higher voltage battery represented by the systems in use today, the majority favor the 6-volt standard.

Variation by Manufacturers. A final difference to be noted is that systems of totally different characteristics are turned out by the same manufacturer. Automobile motors are still a long way from reaching a degree of standardization that permits them to be classified according to horsepower, dimensions, number of cylinders, or any other easily applied standard so far as their requirements from an electrical point of view are concerned. The manufacturer of electrical apparatus accordingly designs a starting and lighting system to meet the requirements of a certain motor and it will give the most efficient service only when applied to that particular motor. This accounts for the major part of the great variation in electrical systems that exists and particularly for the difference between the equipment of the successive models of the same make of automobile. For that reason, it must never be concluded that a Delco, a Gray & Davis, a Bijur, a Wagner, or any other starting and lighting system is always the same on whatever car it may be found. Automobile manufacturers alter the characteristics of their motors from year to year, and the manufacturer of electrical apparatus not only keeps pace with this by redesigning his system to correspond but also introduces various improvements suggested by experience and the development of the art. In consequence, it would be manifestly impossible to attempt to outline in detail the features of every starting and lighting system to be found on all the cars now running, thousands of which are three to five years old. The following analysis accordingly covers only those of more recent manufacture, but by a study of these it will be easy to become familiar with the general characteristics of all, and to note at a glance where improvements have been made from year to year.

STARTING MOTORS

Speaking broadly, there are three classes of starting devices worthy of mention, viz, the mechanical or spring-actuated devices; the compressed fluid devices; and the electrical starters. While still employed to some extent abroad, compressed air and similar devices are now only of historical interest here as they have been displaced almost entirely by the electric starter.

Modern Electric Starting System Anticipated Sixteen Years. Although it has only come into general use within the last few years, the possibilities of the electric starter on the automobile were foreseen at an early day. Those to whom it has appeared as a novel development of very recent adoption will doubtless be surprised to learn that a car embodying many of the features of present-day electrical systems was built in 1896. Indeed, the following description of it might well apply to the present U.S.L. system, which employs the flywheel type of dynamotor. The machine in question was a Diehl specially wound Gramme-ring type designed to operate at 12 volts. The armature, which weighed 111 pounds, served as the flywheel of a two-cylinder horizontal opposed 6- by 7-inch motor. The system was described as follows:

"The flywheel is constructed as a dynamo, which by rotary motion charges a storage battery carried in the vehicle. At the time of starting the carriage, the motorman turns a switch which discharges the storage battery through the dynamo, converting it for a few seconds into a motor, which, being upon the main crankshaft, gives rotation and does away with the necessity of starting the flywheel by hand. After the motor gives the crankshaft a few turns, the cylinders take up their work and the battery is disconnected from the dynamo, which then acts as a flywheel.

"The flywheel dynamo furnishes the current for the induction coil of the sparking mechanism as well as for the electric lamps at night, thus doing away with the necessity of going to a charging station. Attached to the crankshaft is a device for changing the point of ignition of the spark in the combustion chamber, perfectly controlling the point of ignition, acting as a 'lead' and allowing the motors to be operated at a variable speed, according to the work done."

From this it will be seen that as early as the spring of 1896, the present complete electrical equipment of the automobile, including ignition with automatic spark advance, electric lighting and starting, was fully worked out and applied to an actual machine. It was not until sixteen years later that what had been anticipated at such an early day in the history of the automobile became accepted practice in all the essential points mentioned. In addition, the machine in question was provided with a magnetic clutch which automatically connected and disconnected the engine every time the gear-shifting lever was moved, thus anticipating the present-day electromagnetically operated gearbox.

Requirements in Design. The conditions in applying an electric starting motor to the gasoline engine bear no relation whatever to those of the lighting dynamo, so that the problem is not, as might be supposed, merely a question of reversing the functions of a single unit of the same characteristics. Practically the only requirements of the dynamo that differ from standard practice in other fields are that it shall commence to generate at a comparatively low (car) speed and that its output shall not exceed a safe limit no matter how high the speed at which it is turned over. The problem of the starting motor, on the other hand, involves conditions which have not had to be met in the application of electric motors to other forms of service. For example, a very high torque must be developed to overcome the inertia of the load, and the latter takes the form of intermittent rather than of steady resistance to the driving effort, owing to the alternate compression and expansion in the motor cylinders. The trolley car might be cited as a parallel to the heavy starting torque required, but the intermittent load, as well as the highly important limitations of weight, restricted current supply, voltage, and space considerations, are entirely lacking.

In the last analysis, the electric starter is nothing more nor less than a storage-battery starter, since most of its limitations are centered in that most important essential. The matters of driving mechanism, starting speed, and other equally important details can all be based on what is either accepted practice of long standing in other fields, or on the knowledge of starting requirements gained in the years of experience in applying manual effort to that end, but the storage battery will always constitute the chief limiting factor. This should be borne in mind in considering the forms that various solutions of the problem have taken, and, above all, it must be given first consideration in the successful maintenance of any electric starting system, as the majority of troubles met with have their origin in the neglect of the battery.

Wide Variation in Starting Speeds. In view of the long experience in hand-cranking the motor, it would seem that a definite basis for the starting speed would be an easy thing to establish, but this has not been the case. If "motor" briefly summed up in one word all of the varying characteristics to be found in the great variety of engine designs to which starters must be applied, this might have been easier of accomplishment. What suffices to start one make is, however, frequently found to be totally inadequate for others of apparently identical characteristics, so that in the different makes of starters this essential is found to range all the way from 25 r.p.m. to 200 r.p.m. or over. The necessary speed is largely influenced by the carburetion, as with the stand-by battery ignition almost universally provided, dependence need not be placed on the magneto to start; but to draw a mixture from the carbureter of a cold engine calls for speeds in excess of the lower limit of the range given. The most severe service demanded of the starter and the time when it is most needed are coincident, i.e., in winter use, and the equipment must naturally be designed to meet successfully the most unfavorable conditions. Even with starting speeds of 100 r.p.m. or over, it has been found impossible to start some motors without resort to priming. Some idea of the great variation in the speeds adopted will be evident from the fact that the North East starter, as originally built, was designed to turn the Marmon six-cylinder motor over at only 25 r.p.m.; the Hartford on a similar motor at 70 r.p.m.; the Westinghouse, 80 r.p.m.; Delco, 150 to 175, and the U.S.L. at 200 or over. These speeds are not invariable by any means, as in every case the starting equipment is designed particularly for the motor to which it is to be applied, and will run at different speeds in accordance with the requirements of the engine on which it is installed.

Practice Becoming Standardized. So far as practice may be said to have become standardized at the present writing, speeds of 80 to 100 r.p.m. represent a close approach to the average. One of the reasons for making the speed so much higher than could be effected by hand-cranking is the slowing down of the motor as the pistons reach the maximum compression point in the cylinders, while another is the necessity for drawing a charge of fuel from the carbureter under the most adverse conditions so that starting shall always be accomplished without resort to priming.

Voltage. When an engine has been standing idle for some time at a temperature well below the freezing point, the lubricating oil becomes extremely viscous and the current required for starting at a low voltage is very high. The 6-volt standard inherited from dry-cell-ignition days accordingly appeared to be entirely too low at the outset, and several systems employing 12- and 24-volt batteries were developed. The higher efficiency of the latter in starting is opposed by certain disadvantages inherent in this type of installation. Experience has shown, however, that with proper installation and maintenance the 6-volt system affords advantages which more than offset any increase of efficiency derived from the use of a higher voltage, and the majority of well-known starting systems are now designed to operate on a potential of 6 volts.

Motor Windings and Poles. The necessity for developing a powerful torque at low speeds naturally calls for a series-wound motor, such as is employed in street-railway and electric-automobile service, and all starting motors are of this type. Motors built to operate at such a low voltage being new to the electrical designer there is more variation in the form and size of starting motors than exists in power units running on current at commercial voltages.

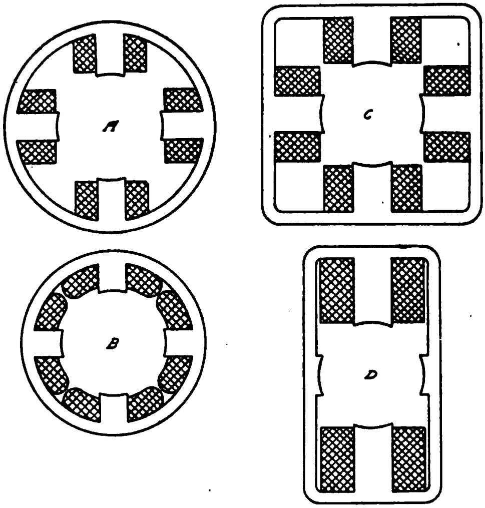


Fig. 154. Cross-Sections Typical Electric Starting Motor
Courtesy The Automobile, New York City

Standard Designs. Briefly stated, the electrical requirements demand a concentrated and correctly proportioned mass of iron and copper in the minimum space. The cross-sections, Fig. 154, show how these requirements have been met in various instances. As the motor is only required to operate for very short periods, both the conductors and insulation can be kept down in size as compared with a motor designed to run constantly under heavy load.

Commercial Forms. The problem is to provide for a certain number of ampere turns around the poles and a magnetic circuit through the latter, as well as steel housing or frame of sufficient cross-section to carry the required degree of magnetization with the shortest magnetic circuit. Consequently, shallow windings with long flat pole pieces are more efficient than the reverse of this form, particularly as air space in the magnetic field lessens its intensity and calls for a heavier winding to magnetize the extra weight of metal to the same degree. Hence, the type represented by *B*, Fig. 154, is the most efficient, in theory at least, of the four forms illustrated.

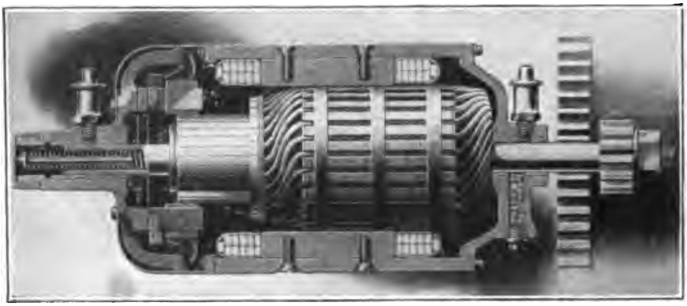


Fig. 155. Section of Bosch-Rushmore Starting Motor

Whether the windings be placed on two poles or on four poles is something that each designer decides according to his own preference in the matter. The Bosch-Rushmore starting motor, Fig. 155, exemplifies type *B* referred to above, except that it is bipolar. Windings and pole pieces of the same type are shown in the Westinghouse starting motor, Fig. 156, this being patterned after form *D* in Fig. 154, though it is of somewhat broader section. The auxiliary

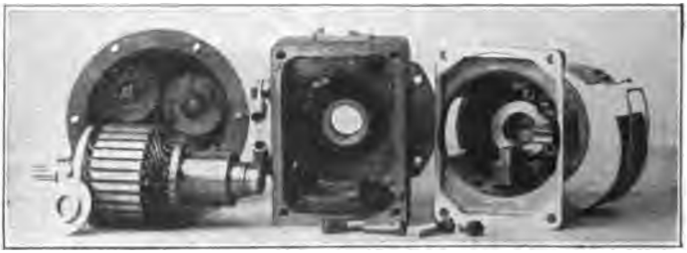


Fig. 156. Westinghouse Starting Motor

unwound pole pieces at the sides do not show very clearly in the illustration; they are of substantially the same form, though considerably wider than those illustrated in the section in question. For a more restricted space a straight rectangular bipolar type is made, Fig. 157. From the standpoint of both electrical efficiency and space considerations, practice favors the cylindrical rather than the rectangular form.

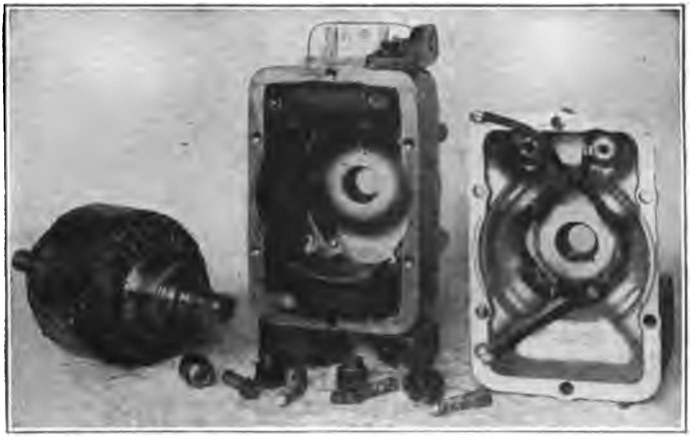


Fig. 157. Bipolar Type Westinghouse Starting Motor

TRANSMISSION AND REGULATION DEVICES

Installation. As the driving requirements of starting with such a small power unit as space and weight limitations make necessary call for a high-speed motor and a high gear ratio to effect the necessary speed reduction, the mounting of the starting motor is totally

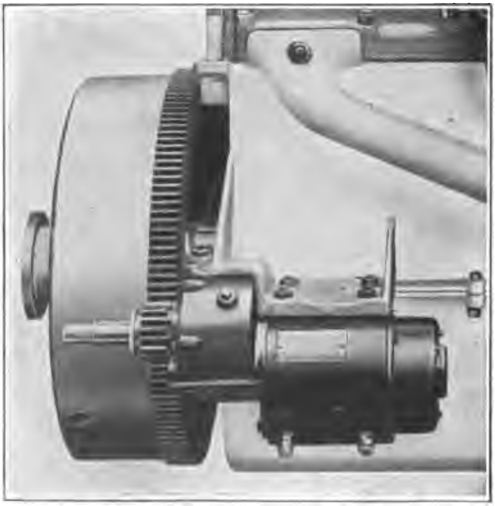


Fig. 158. Double-Reducing Gear Type Installation, Wagner Starting Motor

different from that of the lighting dynamo. The electric motor runs at 1800 to 3000 r.p.m. or over, according to its design, while, as already mentioned, the engine starting speeds usually average 80 to 100 r.p.m. The great speed reduction required is effected in the majority of instances by utilizing the flywheel as the driven gear, a gear being bolted to it, as shown in Fig. 158, which illustrates the application of a Wagner starter to the Moline-Knight 50 horsepower four-cylinder motor. Or the gear teeth may be cut directly in the periphery of the flywheel itself, as shown by the Delco single-unit system mounted on a Cartercar four-cylinder engine, Fig. 159. In either case, this does not afford sufficient reduction in the speed, and an intermediate set of gears is necessary in installations such as those illustrated. This gearing may be mounted as an attachment to the engine or combined with the starting motor, as shown in Fig. 160, showing a Ward-Leonard starting motor with enclosed gearing. In some instances, a planetary type of gear is employed, an example of which is found in one type of the Westinghouse starting motors, Fig. 161, the gearbox being incorporated in the motor housing and

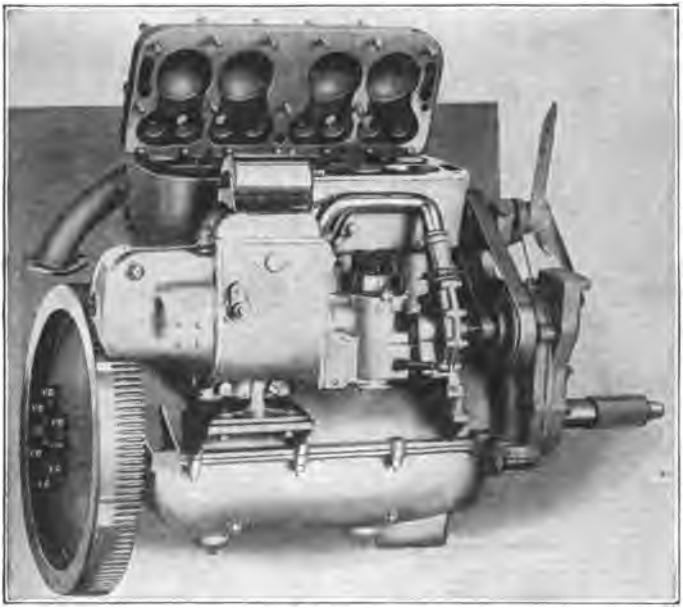


Fig. 159. Mounting of Delco Single-Unit System

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the pinion driving direct. In view of the large reduction available in a planetary gear, a starting motor of this type may be employed to drive through a camshaft or similar location. Planetary gears are also utilized on some of the single-unit systems, such as the Northeast, the gear ratio used being something like 40 to 1 when the dynamotor is used for starting and 1 to 1½ or 2 when running as a generator, Fig. 162. Silent chains are made use of in some cases, but this is done more frequently where a starting and lighting system is applied to an old car rather than to one for which it has been especially designed. Where the starting motor is of a comparatively low-speed type, the single reduction between the motor pinion and the flywheel suffices. Fig. 163 shows a Ward-Leonard starting

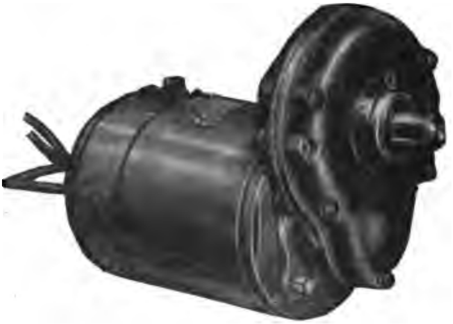


Fig. 160. Reducing Gearing Attached to Ward-Leonard Starting Motor

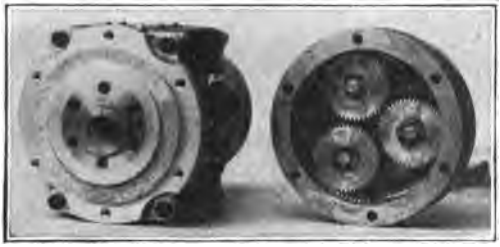


Fig. 161. Westinghouse Starting Motor with Planetary Reduction Gear

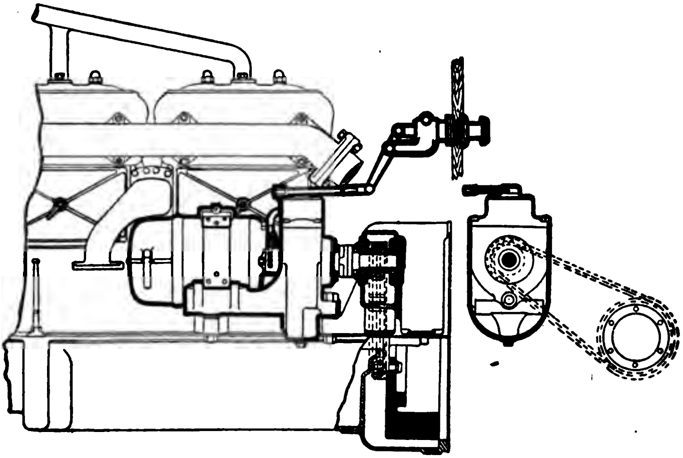


Fig. 162. Mounting and Drive of Northeast Dynamotor

motor designed for direct engagement with the flywheel gear. The purpose of the spring shown on the end of the shaft is to pull the pinion quickly out of engagement when the motor takes up its cycle, as explained in the following sections.

Driving Connections. Except in the case of the single-unit type, which is in a permanent driving relation with the engine, it is necessary to provide some form of driving connection with the engine in order that the electric motor may turn it over to start, and release it the moment the engine fires. The method of accomplishing this is made clear by a brief study of Fig. 164, which shows an Overland four-cylinder motor with an Auto-Lite two-unit system, the starting motor only being shown. In this installation the control button or starting pedal serves both to connect the motor with the battery and to engage the driving pinion with the toothed ring of the flywheel. Typical examples of this form of control are found on the Locomobile and Peerless, which differ only slightly in detail in their methods of installing the Gray and Davis starting motor. The switch is usually located directly beneath the footboards just back of the dash. Depressing the pedal part way makes preliminary contact through a resistance, turning the electric motor over very slowly, and at the same time draws the starter pinion toward the flywheel gear, its slow turning insuring easy engagement. As the pedal is depressed further, it breaks the first contact and closes the main switch, sending the entire battery current through the starting motor and turning the engine

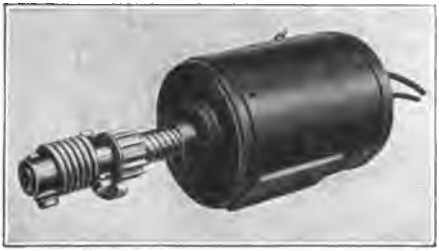


Fig. 163. Ward-Leonard Starting Motor for Direct Engagement

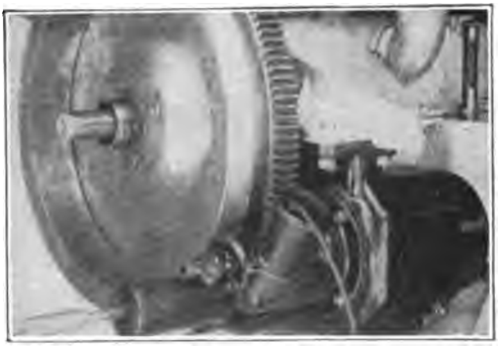


Fig. 164. Auto-Lite Starting Motor on Overland Engine

over rapidly. Releasing the pedal automatically opens the switch contacts and disengages the starting motor from the flywheel. It is also frequently made in the form of a pedal and placed on the slope of the footboards under the cowl of the dash, the location in any case being dictated by the necessity of keeping it out of the way of the other controls of the car.

Automatic Engagement. *Auto-Lite Type.* Fig. 165 illustrates an improvement on the foregoing method, which eliminates the necessity of mechanically engaging the starting pinion with the flywheel. This is an Auto-Lite generator on an Overland six motor. In starting, the depression of the pedal cuts in a resistance in the same manner, at first, as it would not only be unsafe to send the full strength of the current through the motor before it picked up the load, but it would also be impossible to mesh the pinion at full speed. In this starting motor, the pinion is cut on a sleeve surrounding the armature shaft of the motor, and this sleeve is normally held out of engagement by the spring shown. On the armature shaft a thread of coarse pitch is cut which engages the inner surface of the sleeve. When the starting motor begins to turn slowly as the current from the battery enters it through the resistance, centrifugal force moves the sleeve with the pinion along it toward the right until the latter meshes with the flywheel gear. As soon as the current is cut off, the spring draws the pinion out of engagement. This is known as the Bendix drive and is rapidly becoming standardized.

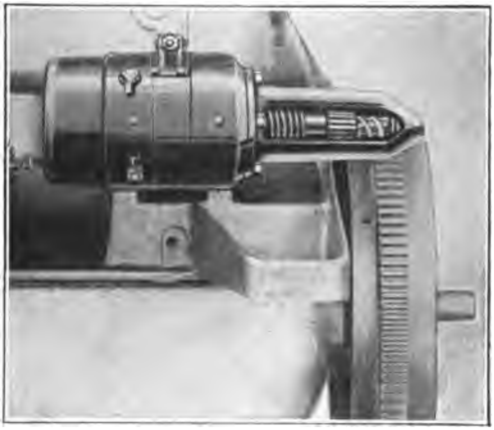


Fig. 165. Automatic Engagement and Release of Starting Motor, Overland Engine

Bosch-Rushmore Type. Another form of automatic engagement, which is electrically operated in this instance, is that of the Bosch-Rushmore starter. By referring back to Fig. 155, which shows a section of this starting motor, it will be noted that there is a heavy spring on the left-hand end of the armature shaft and that the armature itself is normally held out of its usual running position by this spring. In other words, it is not centered in the armature tunnel but is two inches or more to the right of the center of the magnetic field. This is just sufficient to keep the pinion out of mesh when the motor is installed, as shown in Fig. 166. The first contact of the starting switch sends sufficient current for the field poles to exert enough magnetic drag on the armature to draw it back into its normal centered position, at the same time turning it over slowly, so that engagement is quickly effected automatically. The moment the current is shut off, the spring pushes the armature back and disengages the pinion. Exceptions to the practice reflected by the foregoing examples are to be found on cars like the Reo, in which the Remy starting motor is mounted on the transmission housing and drives to one of its shafts through a worm and worm wheel. The latter lowers the speed sufficiently through a single reduction, and the revolution of the armature in starting picks up a clutch which automatically releases as soon as the engine starts.

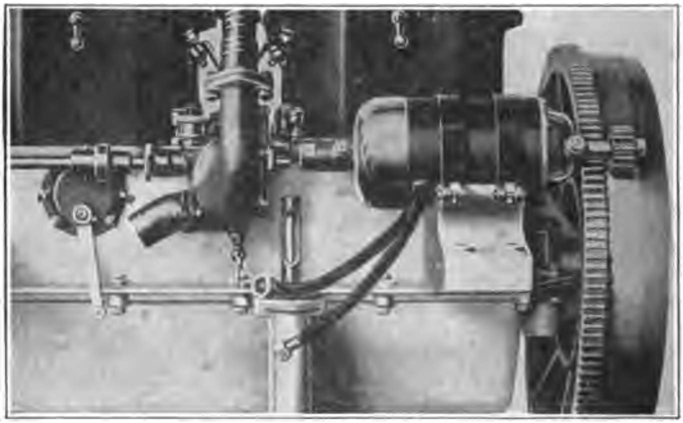


Fig. 166. Mounting of Bosch-Rushmore Starting Engine

Clutches. *Necessity for Disengaging Device.* To prevent the gasoline engine from driving the starting motor when the former takes up its cycle, some form of over-running clutch must be provided unless the starter is geared directly to the crankshaft or has a mechanical disengaging device, such as the Bendix or electrical, as the Bosch-Rushmore and Westinghouse. To take care of the speed reduction, assume that this gear ratio is 30 to 1 and that the throttle is half open when the engine is being cranked. As soon as the explosions begin to take place, the engine will shortly speed up to about 500 r.p.m. Before the gasoline engine is started, however, the electric motor will be running pretty near its maximum rate, say 3000 r.p.m. An electric motor of this type will run as high as 5000 r.p.m. safely, but speeds in excess of this are liable to damage it. If the throttle of the engine should happen to be three-quarters of the way open when started and it should speed up to 1000 r.p.m. before the starting motor was disengaged, the armature shaft of the latter would attain a speed of 15,000 r.p.m., which is far beyond the safety limit. This makes it necessary to provide some device which, while permitting the starting motor to drive the engine, will prevent the latter from driving the starting motor as soon as the former takes up its regular cycle.

A number of different devices are employed for this purpose, such as the jaw clutch similar to that employed on all handcranks, roller clutch, friction clutch, pawl and ratchet, inertia clutch, worm and worm wheel, and others. A description of one or two types will suffice to make clear the principle on which most of the mechanical devices are based. The roller clutch and.the over-running jaw clutch are most frequently used. With starters of the design of the U.S.L., shown on a Sheffield-Simplex (British) six-cylinder motor in Fig. 167, it is obviously unnecessary to provide any form of flexible coupling, as the armature is mounted directly on the crankshaft and consequently cannot exceed the speed of the latter.

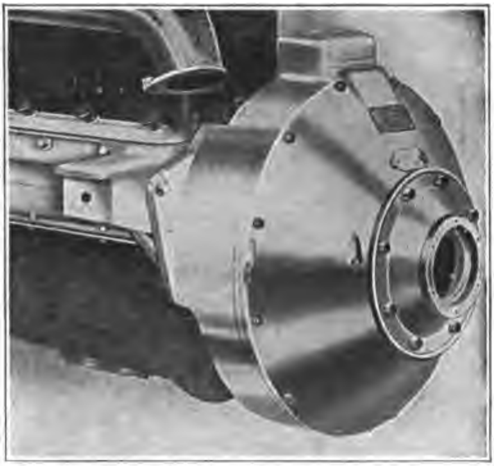


Fig. 167. U.S.L. Dynamo on Sheffield Simplex (British) Engine

Where the crankshaft is driven direct through a train of gears or a combination of gears and a silent chain, the clutch is usually placed between the last gear of the train and the crankshaft. None of the gears is then in operation except when starting. On the flywheel-gear type of installation used in connection with a second-gear reduction by means of a countershaft, Fig. 158, the clutch is placed on the countershaft. Otherwise, it is mounted on the armature shaft. In the case of a worm and worm-wheel drive, it is incorporated in the worm wheel.

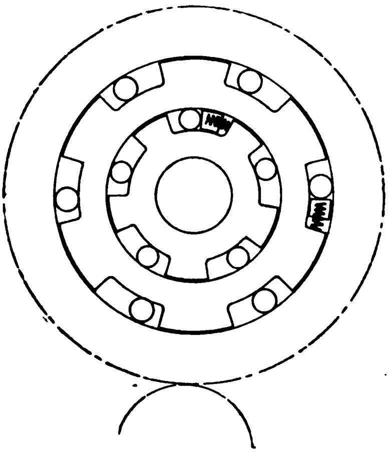


Fig. 168. North East Double Roller Over-Running Clutch (*Horseless Age*)

Roller Type. The roller type is the most commonly used and, as the various forms in which it is made differ but little, a description of one will suffice to make clear the principle employed. It consists of an inner driving member and an outer driven member, connected by a number of rollers when the driving member is rotated in one direction and disconnected when it is rotated in the opposite direction, i.e., when the driven member tends to run faster than the driver. Fig. 168 shows the double-roller over-running clutch employed on the North East dynamotor. A double clutch is employed in this case to permit the dynamotor to be driven at one speed when operating as a dynamo and at another when starting the engine. Fig. 169, which shows the Leece-Neville starter on a Haynes six-cylinder motor, is an example of the use of a roller clutch and chain in place of the gear and pinion connection previously described.

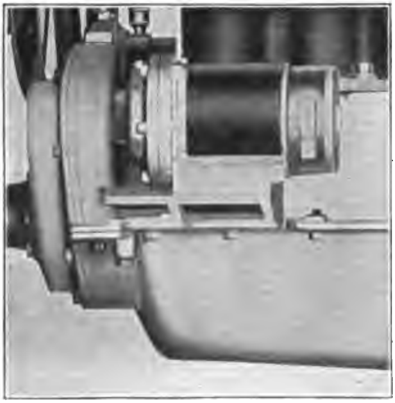


Fig. 169. Leece-Neville Starter Installation, Haynes Motor

Back-Kick Releases. As the starting motor has more than sufficient power to overcome a back-kick or premature explosion (with the spark-timing lever too far advanced) of the engine, and is only slowed down by it, only a few instances of the employment of a back-kick release are found in practice. One of these on the Northeast starter is in the form of a friction clutch held in contact by springs. This clutch will slip under such circumstances. A friction disc clamped between two steel discs, similar to a shock absorber, is employed on the Hartford starter, this being required because of the irreversible worm and worm-wheel drive used, as the teeth of the latter would be injured in case the engine "back-kicked". Another device employs a brake band on the starting gears so designed that it holds in one direction only.

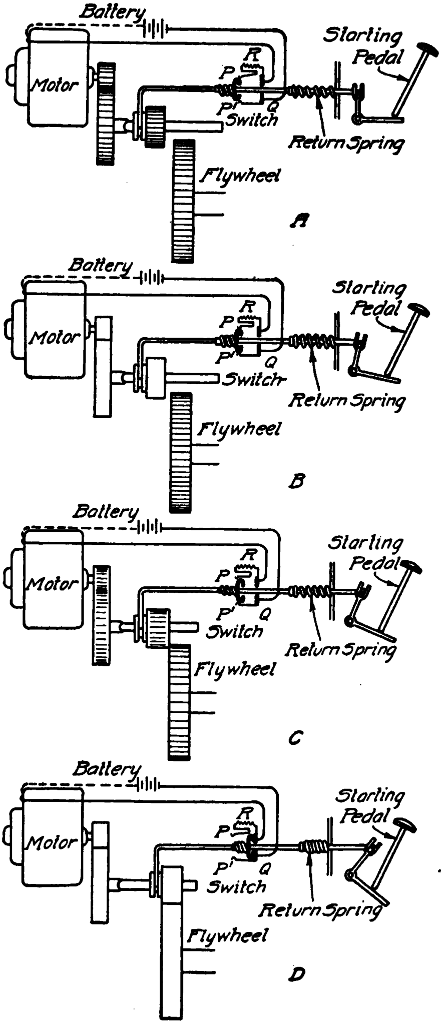


Fig. 170. Diagrams of Electrical and Mechanical Connections of Motor and Switch for Flywheel Drive with Double-Gear Reduction (*Westinghouse*)

Switches. Two types of switches are employed in connection with starting and lighting systems—those designed to control the lighting circuits to the various lamps, and those employed to connect the battery with the starting motor. As the first type seldom carries more than 5 amperes at 6 volts and proportionately less at higher voltage, it does not differ from the standard forms of switches employed for house lighting, except that it is made much smaller in size. The starting switch, on the other hand, has to carry currents ranging from 50 to 250 amperes or more at voltages varying from 6 to 24, so that such a switch must be well built mechanically and have liberal contact areas. On account of the heavy currents handled by these switches there is a tendency to destructive arcing at the contact points unless provision is made to prevent it.

Westinghouse Starting Switch. For starting use, two forms of switches are employed according to the method by which the motor starts the engine. Where the motor is connected directly to the battery terminals by the switch, as in the case of single-unit systems such as the Delco, only a single set of contacts is necessary; but in case gears must be engaged before the starting motor can take the full battery current, two progressively operated sets of contacts are used. The first set completes the circuit through a heavy resistance to turn the starting motor over very slowly, and the second set cuts out this resistance, the driving gears then being engaged. The operation of a switch of this type is graphically illustrated by a series of sketches, Fig. 170, showing a Westinghouse starter installation. In sketch *A*, both contacts are open, the return spring holding them apart. When the starting pedal is partly depressed, as in sketch *B*, the first set of contacts *P* come together and current from the battery passes to the starting motor through the resistance *R*. This connection continues through the spring fingers *P* and *Pl* until the sliding member is almost in contact with the main-switch points *Q*, when it is broken and the circuit is directly closed with the battery by a butt contact. The operation only requires a fraction of the time necessary to describe it. The moment the foot is removed from the starting pedal, the return spring automatically breaks the circuit. The construction of this switch is shown in Fig. 171. Switches of this type are usually mounted directly under the footboards, a slight movement being sufficient to close the contacts. The starting plug may be removed by

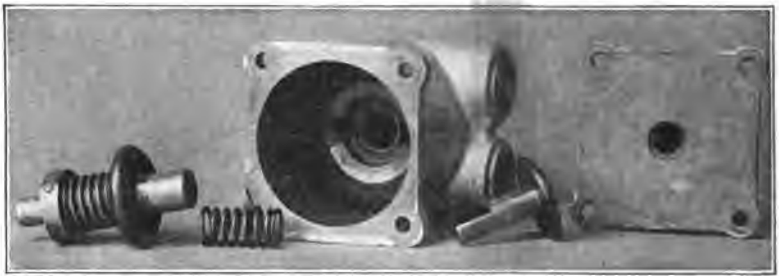


Fig. 171. Details of Westinghouse Switch

the driver when leaving the car to prevent tampering, a pin across the tube making it impossible to insert a pencil or stick. The resistance mentioned is in the form of a ribbon and is incorporated in the switch.

Miscellaneous Starting Switches. The type of switch used in connection with the Remy system is shown in Fig. 172. Both this and the Westinghouse switch described are known as butt-contact switches. The knife type of switch is also employed in several systems, Fig. 173 showing the Dean switch of this class. A somewhat unique form of contact is shown in the Gray and Davis switch, Fig. 174. There being no starting gears to mesh, it is only necessary to turn the current directly from the battery into the motor to start. *P* is the foot button of the starter, *F* the floorboard of the car, and *T* and *M* the terminals of the switch from which cables are led to one side of the battery and to one of the motor brushes, the others being grounded, as this is a single-wire system. Into the cast receptacle of the switch is fitted an insulating disc carrying the contacts *C* and *O* and also serving to insulate the terminals. These contacts are circular in form, and their free ends are turned away from each other so as to slip down over the knives *R* and *S* set in the insu-

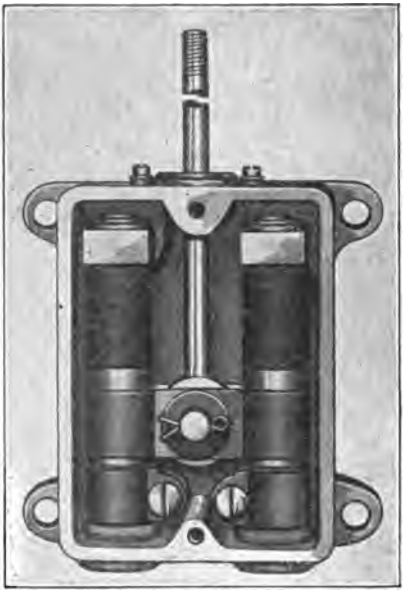


Fig. 172. Remy Starting Switch

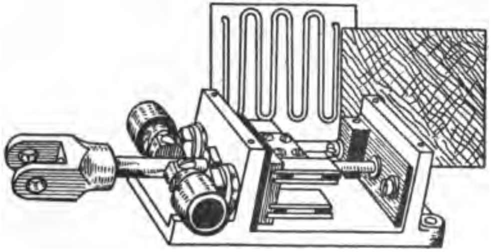


Fig. 173. Dean Knife Starting Switch

lated disc. The contacts are pressed downward by *P*, which is returned by the spring *G* pressing against the spindle *P*. The terminals *T* and *M* are fastened to the semicircular knives *R* and *S*, respectively, so that bringing down the contacts *C* and *O* upon these knives completes the circuit from *T* to *M*. Numerous other forms of foot-operated switches are also employed, the Gray and Davis laminated contact switch, Fig. 175, for flywheel-gear installations, and the Ward-Leonard "harpoon" type, Fig. 176, being representative examples.

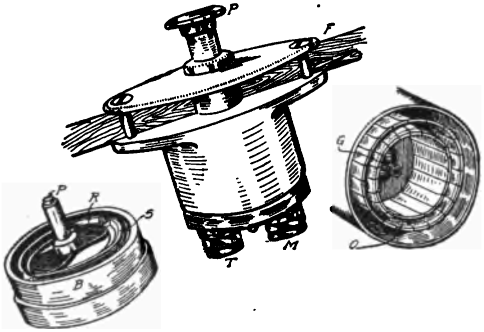


Fig. 174. Gray and Davis Button Starting Switch

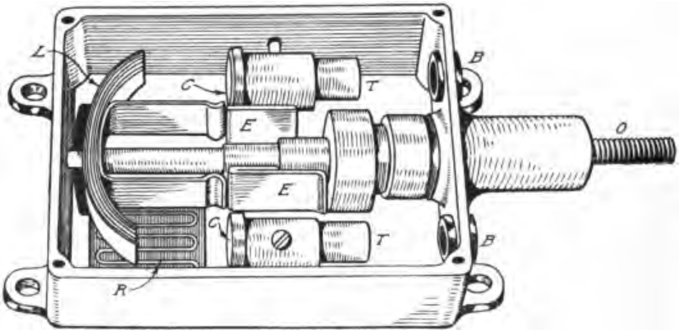


Fig. 175. Gray and Davis Laminated Type of Starting Switch
Courtesy of The Horseless Age

Electrically Operated Switches. In this type a conventional push-button switch, either on the dash or mounted on the steering column, as shown in Figs. 177 and 178, which illustrate the Packard and Overland control, respectively, takes the place of the foot button. This push-button switch, however, only handles a shunt current of low value, which energizes a solenoid to close the contacts of the main switch and also to engage the gears where this is necessary. The Westinghouse magnetically operated switch is explained in detail in connection with the description of that system. This form of control is employed on electric-railway trains and on electric automobiles. In addition to housing the push-button switch of the starting system, the two steering column control units mentioned also incorporate all the switches necessary to control the entire electrical equipment of the car, as will be noted by the indications alongside the various buttons on the Overland controller. A complete wiring diagram of the Packard six-cylinder controller is shown in Fig. 144.

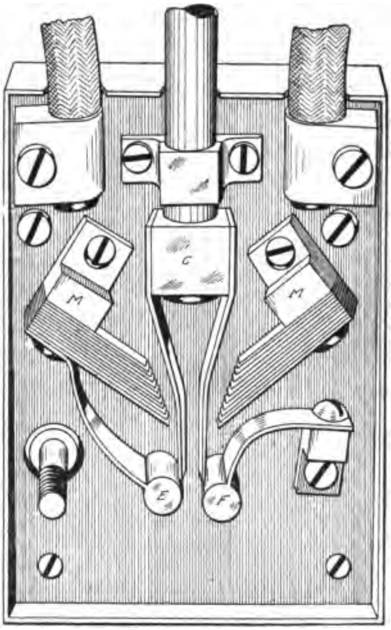


Fig. 176. Ward-Leonard "Harpoon" Starting Switch

Where a higher potential than the usual 6-volt standard is employed, the switch has another function, which is that of changing the battery connections from the multiple arrangement used for lighting to the series connection necessary to send the full voltage and current of the battery through the starting motor. This is the case with the U.S.L. system, which is made in either 12—6-volt or 24—12-volt forms.

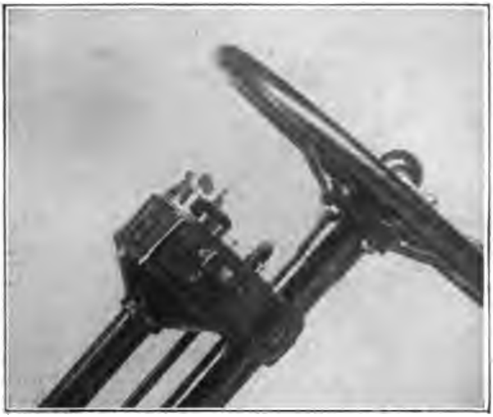


Fig. 177. Packard Electrical Control

Fuses. Standard practice favors the employment of fuses on all the lighting circuits to protect the battery in case of short-circuits in any of the wiring. They were originally considered unnecessary on two-wire systems, but have since been adopted on the latter as well as on the single-wire system. Such fuses are of the cartridge type of miniature size, as shown in Fig. 179, which represents a Westinghouse fuse block, and do not produce a flash when they blow, which is a safety feature of importance in the presence of gasoline. The appearance of a black spot on the label indicates that the fuse has burned out, or these fuses may be had in glass tubes through which the fuse wire is visible.

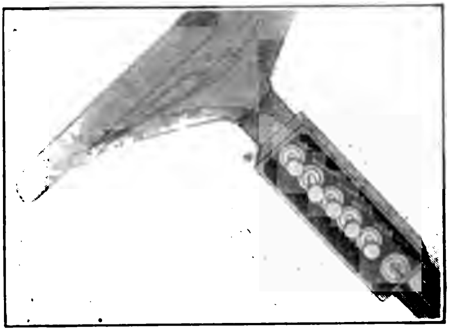


Fig. 178. Overland Electrical Control

A double reading ammeter, mounted on the dash and illuminated at night by a hooded lamp, shows whether current is being sent into the battery or being taken out of it, the needle usually moving over a scale to the right of the neutral line for charging and to the left for discharging, Fig. 180. This dash lamp is usually connected in series with the tail lamp, so that when it goes out it is an indication that the tail lamp is out as well. A voltmeter sometimes is provided to indicate the condition of the battery. In the Bosch system, this is combined with the lighting switches, as shown in Fig. 181.

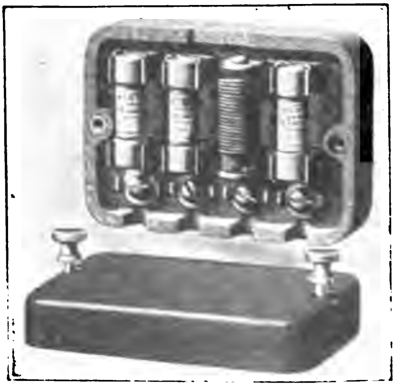


Fig. 179. Type of Fuse Employed on Lighting Circuits

In some systems, an indicator is employed instead of an ammeter, a movable target appearing at a small opening in the instrument and simply reading "Off" and "On" or "Charge" and "Discharge". Such an instrument need not be so accurate as an ammeter and is more durable. These indicators never came into general use, however, and will be found comparatively few cars, usually models of two or three years ago.

Electric Horns. The use of a storage battery which is of sufficient capacity for starting purposes and which is kept constantly charged by the lighting generator has made it possible to employ numerous auxiliary electrical devices. The electrical horn is the chief of these, and it has to a very large extent displaced warning devices of every other class. Two different types of electric horns are used, in both of which the sound is produced by the vibrations of a sheet-metal diaphragm several inches in diameter. The only difference between the two forms lies in the method of causing this diaphragm to vibrate, one employing a small electric motor and the other a simple electric magnet. Fig. 182, which is a phantom view of the operating mechanism of a Klaxon horn, shows the first type. On the upper end of the armature shaft of the electric motor is fastened a toothed wheel which strikes the button in the center of the diaphragm and sets it vibrating at the rate of several thousand times per minute, giving rise to the raucous squawk which has come to be identified with automobile warning signals. As shown in Fig. 183, which illustrates a section of the Apollo horn, this type is nothing more nor less than an ordinary buzzer on an enlarged scale.

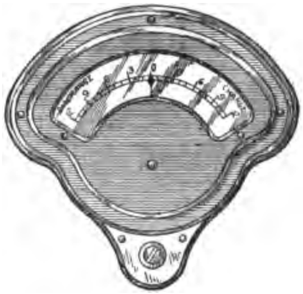


Fig. 180. Gray and Davis Ammeter

Fig. 181. Bosch Voltmeter and Switches

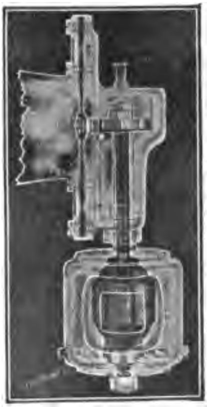


Fig. 182. Phantom View Klaxon Horn

The armature of the electromagnet vibrates at high speed producing a sound by taps on the rod attached to the diaphragm.

Care of the Electric Horn. As the operation of the electric horn is based upon exactly the same principles as the essentials of the starting and lighting systems, the instructions given for the care and adjustment of the latter will apply to it as well. In the case of the motor-driven type of horn, the commutator and brushes of the motor will require attention from time to time. Failure to operate may be due to a broken connection at the horn or at the battery; ground in the circuit between it and the battery; brushes not bearing properly on the commutator; or an excess of oil and dirt on the latter. If the motor runs properly, but the horn produces either no sound or a very weak sound, the trouble will be due to the poor contact of the toothed wheel with the button on the diaphragm. This button is made glass hard to obviate wear at that point, but, in time, replacement of either the button or the toothed wheel or of both may be necessary.

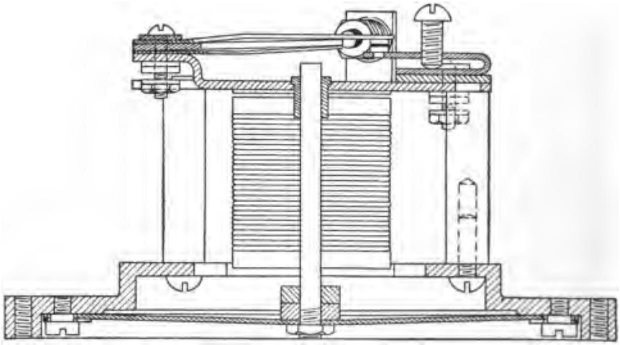


Fig. 183. Mechanism of Apollo Electric Horn (*Horseless Age*)

The attention required by the vibrating type of horn, of which there are many thousands in use, is very similar to that described for the battery cut-out and the voltage regulator. The contact points will require cleaning, truing up, and adjustment at intervals, and the spring may also need occasional attention. Failure to operate may be caused by a loose connection or break in the circuit, or by a lack of adjustment which causes the contacts to be held apart so that no current can pass through the winding of the electromagnet. A weak sound from this horn will result either from insufficient current or from lack of adjustment.

LIGHTING

For automobile headlights, side lamps, tail lamps, and general illumination, electric lighting has superseded all other systems. In the best electric-lighting systems the current is supplied by a dynamo driven constantly by the engine, with a storage battery auxiliary.

Incandescent Lamps. *Tungsten and Other Filaments.* Incandescent lamps are usually provided with tungsten filaments. These filaments are much shorter and much stronger than in standard lamps, a condition that is further contributed to by the necessities of low voltage and high amperage, which require short and thick rather than long and thin filaments. A good tungsten lamp will afford 1 candle power of illumination for each 1.2 watts of current.

Mazda Type. Fig. 184 shows the standard types of lamps generally used. These are Westinghouse Mazda lamps for 6 volts, those at the left being 15 c.p. headlight lamps; the next two, 6 c.p. side-light lamps; and the smallest one is a 2 c.p. size designed for the tail light, meter light, and for interior lighting of closed cars. At 6 volts, the 15 c.p. lamps require 2.5 amperes, the 6 c.p. side lights 1.25 amperes, or where 4 c.p. lamps are employed—a better size for the purpose—.85 ampere; the 2 c.p. lamps take .42 ampere. The larger lamps have the filament in the form of a spiral coil occupying the minimum space so that the whole source of light can be placed at the exact focus point of the paraboloidal reflector.

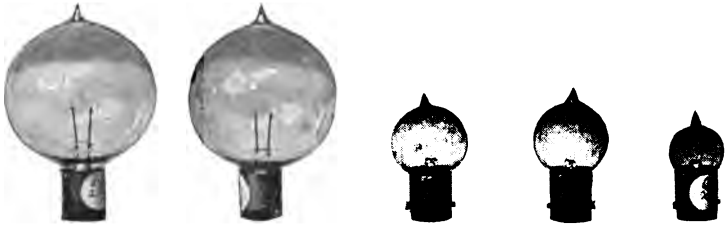


Fig. 184. Westinghouse Lamps—Head, Side, and Tail

Bosch Type. Fig. 185 shows the Bosch lamps, which are of special form. The headlight lamp at the right is of 25 c.p. and has the filament stretched horizontally across wire supports, while the side lamps of 8 c.p. have a loop of corrugated wire, and the tail lamp, of tubular form, a single filament running straight across it. Tail lamps are usually in series with the instrument lamp so that failure of the latter to light also indicates a failure of the tail lamp.

Lamp Voltages. When Edison was asked how he came to hit upon 110 volts as the standard for incandescent lighting, he said he "just guessed it". Evidently the 6-volt standard came about in pretty much the same way. It is not practicable to operate small lamps at a high voltage, as the lamp of that type requires a long slender filament. Many manufacturers of starting apparatus have deemed it necessary to employ a higher voltage, but the lamps are usually run at 6 volts, so that the batteries employed are accordingly some multiple of 3, as 6, 9, or 12 cells, giving 6, 12, 18, or 24 volts. Where more than three cells are used, this necessitates operating the lamps from a part of the battery, which is not advantageous, as it involves discharging the battery unevenly. As a battery capable of delivering current at 12 volts weighs and costs about 35 per cent more than one giving current at 6 volts and the attention required is greater, the lower voltage is generally favored.

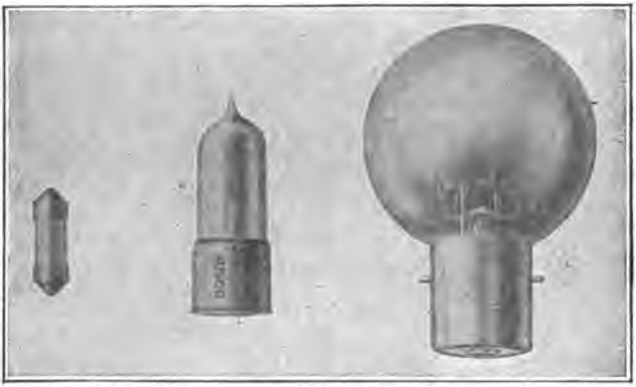


Fig. 185. Bosch Type Automobile Incandescent Bulbs

Fig. 186. Typical Electric Automobile Headlight

Lighting Batteries. The only type of batteries suitable for electric lighting—except for very small tail lamps, which can be successfully kept in operation by dry cells—are storage batteries of the lead types, as described in Part VIII.

Reflectors. Much attention has been directed to the problem of defining the best type of reflectors for automobile headlights, and the conditions of lighting by acetylene gas have been determined to be very different from those involved when electric lighting is used.

Parabolic Type. A typical electric headlight for automobile use is that illustrated in Fig. 186. The plain form affords a minimum tendency to catch dirt and mud and greatly simplifies cleaning. The position of the lamp is adjusted to give correct focus, as this is essential to give a properly projected beam of light ahead on the road.

Comparison of Parabolic with Lens Type. The reflector in the foregoing lamp is of the deeply parabolic metal type, illustrated in Fig. 187. The advantage of this type of reflector is that it intercepts a much larger proportion of the light rays from the lamp than the lens-mirror type of reflector, Fig. 188.

Types for Various Locations. Fig. 189 *-a*, *-b*, *-c*, *-d*, and *-e* show the usual types of lamps employed. These are, in the order given, an outside side lamp, flush-type side lamp, two types of electric tail lamps, and a cowl or dash lamp for illuminating the instruments, such as the ammeter, oil telltale, and the like. Fig. 189*-f* shows a magnetic trouble-hunting lamp, the base of which attaches itself to any metal part of the chassis.

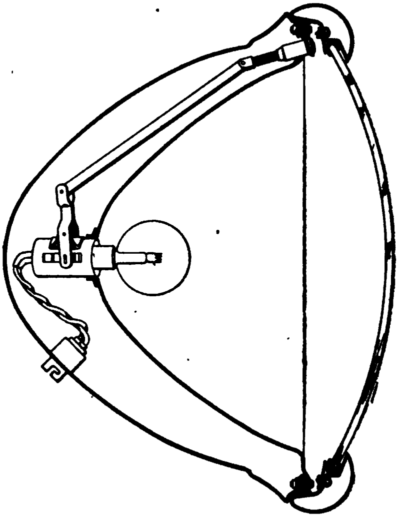


Fig. 187. Section of Fig. 186

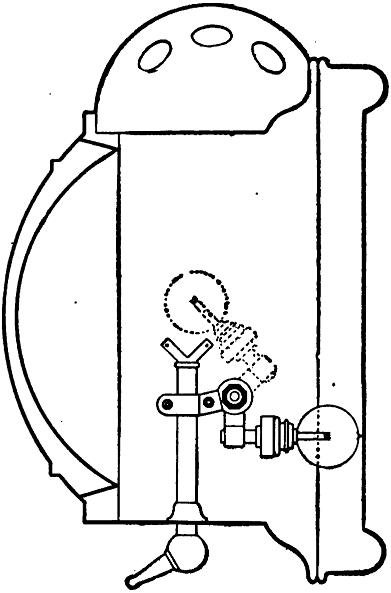


Fig. 188. Mangin Lens Reflector

Headlight Glare. The increased efficiency of electric headlights has brought with it, in far more aggravated degree, the blinding glare first experienced with the acetylene lamps. Originally, strong headlights bothered pedestrians; but since the introduction of electric lighting, they have been objected to most strongly by automobilists themselves, because to the driver of an automobile, the blinding glare from the headlights of an approaching car means not only annoyance but danger. Acuteness of vision is wholly destroyed for a period of thirty seconds or more during which only a slow-down to a walking pace will insure absolute safety to the automobilist, as a pedestrian or the usual black and lampless buggy are practically invisible.

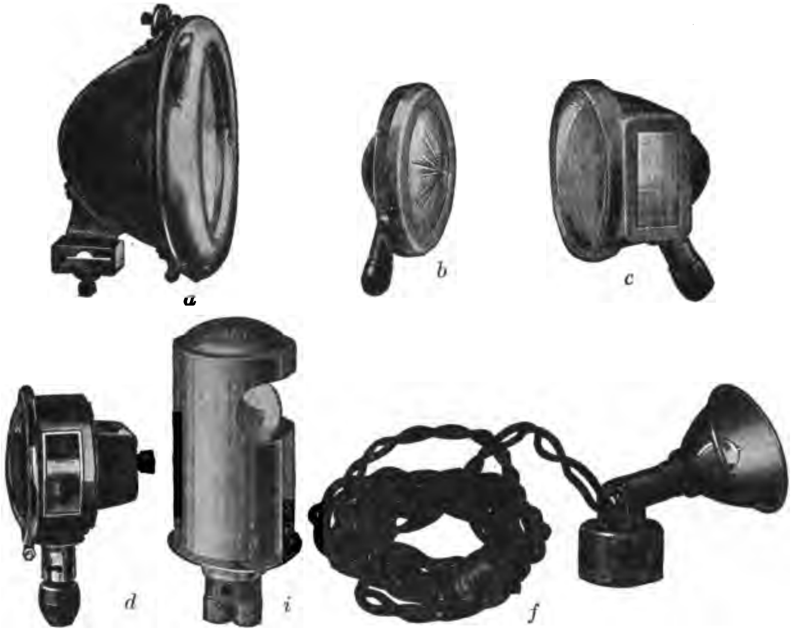


Fig. 189. Types of Side, Dash, Tail, and Trouble-Hunting Lamps

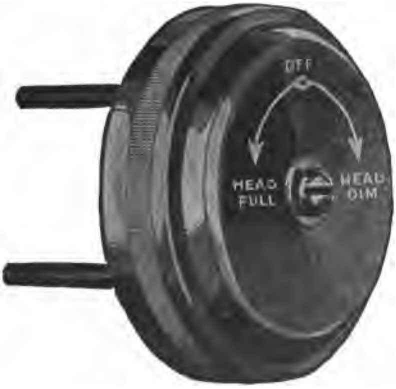


Fig. 190. Type of Headlight Dimming Switch

Dimming Devices. Owing to the fact that glare and illumination are so closely related and that there is no objection to glare on deserted country roads where the necessity for road illumination is greatest, permanently dimmed lights are naturally not practicable. What is required is a device under the control of the driver, so that either the full illuminating power of the head lamps or a subdued or dispersed light, free from glare, may be had as required.

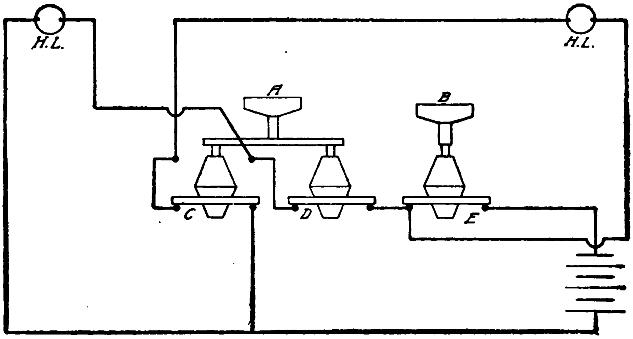


Fig. 191. Wiring Diagram of Parallel Control for Dimming Headlights
Courtesy of Horseless Age, New York City

A great many fundamentally different devices have been offered as a solution of the problem. While differing radically, practically all of them may be classed under two heads, i.e., electrical and mechanical.

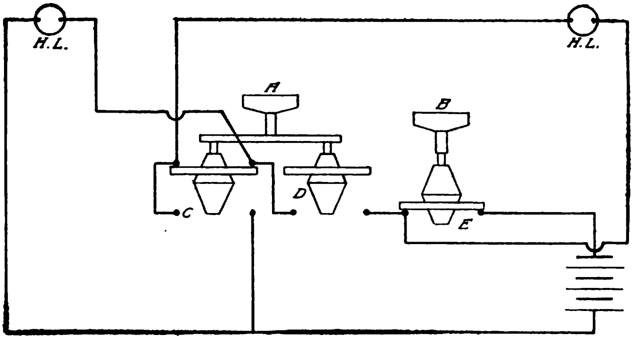


Fig. 192. Wiring Diagram of Series Control for Dimming Headlights
Courtesy of Horseless Age, New York City

Electrical Devices. One of the simplest of this class that has met with considerable favor is nothing more nor less than a *resistance* that may be inserted in the circuit of the headlights by turning a small switch, mounted either on the steering wheel or in some other easily accessible location. This cuts the voltage down and causes the lamps to burn a dull red, instead of the filaments being the dazzling white reached at full incandescence. A dimmer of this type is shown in Fig. 190. An equally simple and practical device is a switch to throw the headlights into series for a dim light and back into parallel again when full illumination is desired. With the series connection, the current must pass through both lamps successively and each bulb thus receives but half the voltage and, as even a comparatively slight drop in voltage causes the efficiency of an incandescent lamp to fall off very markedly, the same result is attained. It is equivalent to burning a 6-volt lamp on a 3-volt current. With the normal, or parallel, connection, the current flows through each lamp separately, and both receive the full voltage of the battery so that they burn at full brilliance. A switch of this kind is marketed by the Cutler-Hammer Company. Fig. 191 illustrates the connections for parallel arrangement, or full illumination, switches *D* and *B* being closed and the button *A* pulled out to make *C* contact with its lower set of

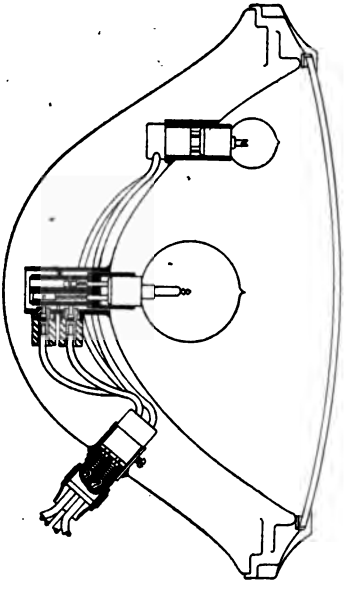


Fig. 193. Section of Hall Double Headlight

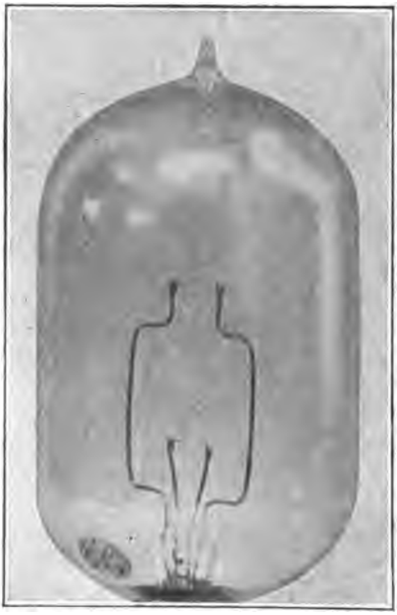


Fig. 194. Jeffery Double Filament Lamp

connections. Fig. 192 shows the connections for series burning, effected by pulling out button *B* and pushing in *A*, this closing switch *E*, opening *D*, and contacting *C* with the upper connections.

The use of *two bulbs in each headlight* is also commonly resorted to, the method of effecting this being shown in Fig. 193. The second bulb is of the size ordinarily employed for side lights and is, moreover, entirely out of the focus of the reflector, so that the diminished light produced is entirely without glare and is mostly diverted downward.

A similar end is attained by the use of *two filaments in the same bulb*, as shown in Fig. 194. The lower filament in this case is employed for full illumination, and the upper, which is out of focus, for the dimmed light. This has the disadvantage that the burning out of either one of the filaments makes it necessary to replace the lamp, while both filaments also require the same amount of current.

PRACTICAL ANALYSIS OF TYPES

EXPLANATION OF WIRING DIAGRAMS

Significance of Symbols. To be successful in running down the cause of defection in a starting and lighting system on a car involves, first of all, a knowledge of the most likely places to seek the trouble.. Unless the trouble is very apparent or becomes so upon making the simplest tests, a process of elimination must be carried out, and, to do this with any degree of system, the trouble hunter must be perfectly familiar with wiring systems in general. To the uninitiated, wiring diagrams are nothing more than a jumble of lines, queer figures, and confusing signs. Familiarity with these signs, in consequence, is the first thing to achieve. Their direct bearing upon the varying relation of the essentials described in the introductory on Electrical Principles, Part I, will at once be apparent.

Current Direction. The plus and minus, or positive and negative signs, + positive, – negative, scarcely call for any extended explanation. They indicate the direction in which the current flows. It is of the utmost importance, where the manufacturers' directions are to connect certain apparatus with a given wire to the plus, or positive, side, and another wire to the negative, that these instructions be followed explicitly. Otherwise, the apparatus either will refuse to work or it may be damaged, as in the case of a storage battery on which the connections have been reversed. Wherever

+ **Positive**

— **Negative**

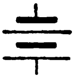


Fig. 195. Battery, Either Storage or Dry Cells

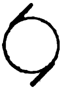


Fig. 196. Generator, Commutator, and Brushes

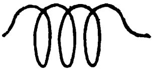


Fig. 197. The Proper Method of Showing a Coil Which Surrounds an Iron Core but Very Seldom Used on Delco Drawings

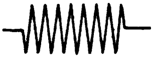


Fig. 198. The Method Used in Showing a Coil Where There Is No Chance of Confusion—Used in Field Coils, Ignition Coils, Etc.

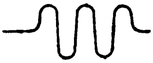


Fig. 199. The Method Used to Show Resistance Such as a Resistance Unit and Charging Resistances

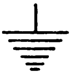


Fig. 200. Ground Connection Where the Wire Is Connected to the Chassis, Engine, or Generator

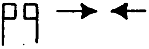


Fig. 201. Contact Points Such as in Switches, Distributors, Etc.

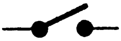


Fig. 202. Method Used to Show Lighting Switches

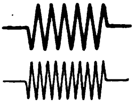


Fig. 203. Primary and Secondary Windings of an Ignition Coil

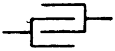


Fig. 204. Condenser

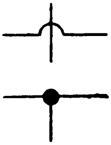


Fig. 205. Upper Showing Crossed Wires not Connected. Lower Showing Connection in the Wiring

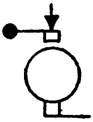


Fig. 206. Motor Commutator and Brushes with Brush Lifting Switch

it is necessary that the current flow through a piece of apparatus in a certain direction, the manufacturer stamps plus and minus signs at the terminals.

Battery; Generator. A battery, regardless of its type, is always shown by alternate heavy and light lines, as indicated in Fig. 195, each pair of lines representing a cell, so that the number of cells in the battery may be told at a glance. Other sources of current, such as generators, are indicated by a conventional sign consisting of a circle with two short heavy lines tangent to its circumference at opposite points and usually at an angle to the horizontal, as shown in Fig. 196. The origin of this sign will be apparent in its resemblance to the end view of a commutator with a pair of brushes bearing on it. This sign is also used to indicate a motor, in which case the letter **M** is inserted in the circle.

Coils. Coils which are wound on an iron core are generally indicated by a conventional sign consisting of a few loops of wire, as in Fig. 197, but this is only the case where such a coil occurs at a place in the circuit where there might be a chance of confusion in identifying it. Where there is no possibility of confusion—as in the case of the windings of a generator or motor, ignition coils, and the like—the sign shown in Fig. 198 is often used. Where the lines are heavy, a coarse wire, such as is employed for series windings of generators or motors, or the primary winding of an ignition coil, is intended.

Resistance. Resistance in a circuit is usually shown by an arbitrary sign, Fig. 199, similar in outline to a piece of the cast-iron grid frequently used in charging resistances, though sometimes shown as a coil and marked "resistance".

Grounds. The sign of a ground connection is the inverted pyramid of short lines, Fig. 200, and indicates that the circuit is grounded. This may be either by a wire directly connected at some point with the frame, as in the case of the storage battery, or it may be through an internal ground connection in the apparatus itself, as in the lamps and sometimes the generator or motor, the connection being made simply by fastening them in place. In any case, the sign indicates that the circuit is completed through a ground.

Contacts. There are a number of signs employed to indicate contact points, switches, and the like, and, where they are not of an arbitrary character, such as Fig. 201, which shows contact such as used in switches, distributors, etc., and Fig. 202, which indicates a lighting switch (Delco diagrams); they usually will be found to bear sufficient resemblance to the apparatus itself to make their identification easy.

Induction Coil. Fine lines indicate a generator shunt winding, the secondary of an ignition coil, or the coil of a relay or cut-out. The primary and secondary windings of an induction coil as used for ignition are indicated by a fine and a coarse coil sign, as in Fig. 203.

Condenser. A condenser with its overlapping plates is shown in Fig. 204.

Crossed Wires. To show wires that cross one another without making connection, a half loop is made at that point to show that the wires do not touch, as in Fig. 205, while wires that are connected are shown by a black dot at the junction.

General and Special Usage. While these signs are not universally used in exactly the form shown here, their employment is very general and in the majority of cases, such as the positive and negative, battery, ground, generator, induction-coil windings, and coil signs, they are never changed. In some instances special signs are employed, such as that shown in Fig. 206, which indicates the motor commutator of the Delco single-unit machine or *dynamotor*, and shows the special brush lifting switch. Incandescent lamps are almost always indicated by small circles, though the lamp itself is sometimes drawn in. As a matter of fact, very little system is followed by different makers in making these wiring diagrams. In an effort to simplify its reading to the uninitiated, a diagram will sometimes picture most of the apparatus in such form that it will be recognized from its resemblance to the original, including the battery, generator, lamps, and the like, using only signs for showing coils and ground connections; others go to the opposite extreme and show nothing but signs.

Diagrams for Single-Wire System

Buick-Delco Type. For purposes of illustration a very simple diagram is selected, Fig. 207. This is the Delco single-unit system as employed on an earlier model of the Buick. Starting at the left side of the diagram, the generator is shown with its shunt-field winding, one brush of the generator and the shunt coil being grounded. This is a complete circuit, but, as the shunt coil has a high resistance, only a very small part of the current flows through it. The series winding of the generator is shown at the top and the explanation that this is a "reverse" series coil means that it is wound to have a polarity opposite to that of the shunt coil. It accordingly opposes the shunt coil at the higher speeds and serves to regulate the output of the generator. This is the familiar bucking coil or "reversed compound winding".

To reach the battery, the current from the generator must pass through the automatic cut-out, the two windings and the contact points of which are shown a little

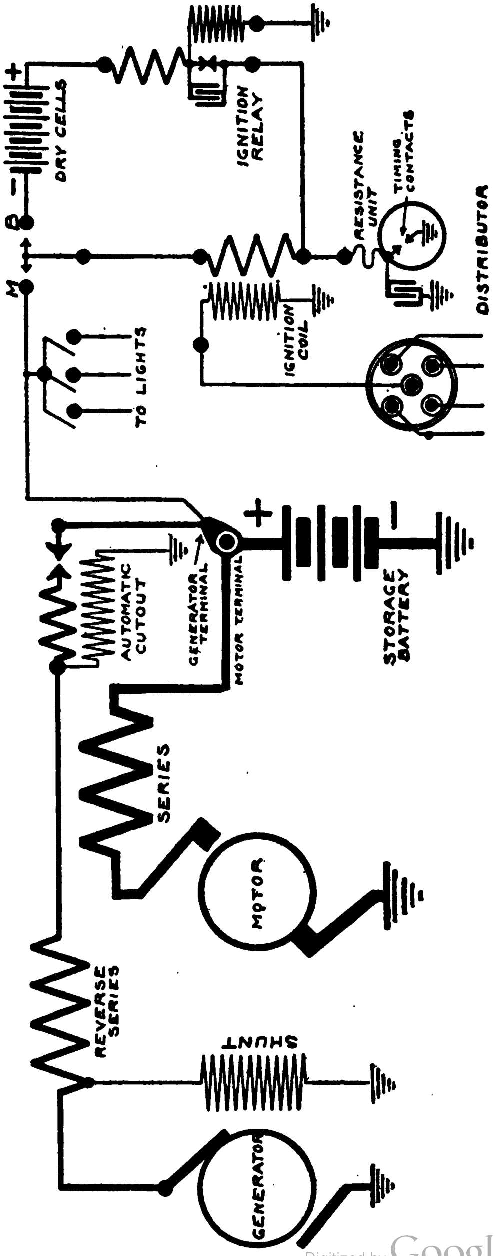


Fig. 207. Wiring Diagram for Delco Single-Unit Single-Wire System

further to the right along the top line. If the ammeter on the dash fails to register any charging current when the engine is running at a speed equivalent to 10 miles an hour or more, the automatic cut-out would be the first place to seek a break in the system. Under normal conditions of working, the cut-out closes the circuit as soon as the generator reaches a certain speed and the 3-cell storage battery, one side of which is grounded, is then being charged, the current entering at the plus or positive terminal and returning by way of the minus terminal or pole through the ground connection. (In some systems, such as the Gray & Davis, the frame of the car is the positive side of the circuit.)

Between the generator and battery circuits is shown the starting-motor circuit. The width of the lines employed indicates that very heavy conductors are used in this circuit and they are necessary owing to the extremely heavy currents handled. The series winding of the motor field is also short and of heavy wire. The upper brush of the motor being in a raised position indicates that the motor is brought into operation through a switching brush, and when this switch is closed to start, one of the generator brushes is raised from the commutator. This completes the generating, starting, and controlling circuits, all of which are shown to the left of the battery. The relative difference in thickness between the wires of these circuits at the left and those at the right for the lighting and ignition show the difference in the amount of current handled by the two. The double set of contact points at the center along the top line indicate the dash switch—turning this to the left giving the magneto connection *M*, while throwing it to the right *B* puts in the battery of six cells shown just a bit further to the right in the ignition circuit. To the left of this dash switch a tap has been made for the lights, the three circuits of which, head, side, and tail are indicated but not completed, the draftsman often taking it for granted that complete detail connections are unnecessary. Another instance of this will be seen just below the lighting switch, the leads from the high tension distributor (four indicating a 4-cylinder motor) ending up a short distance from it, as it is obvious that they lead direct to the spark plugs.

The primary and secondary windings of the induction coil (ignition)—the former of which is grounded through a resistance

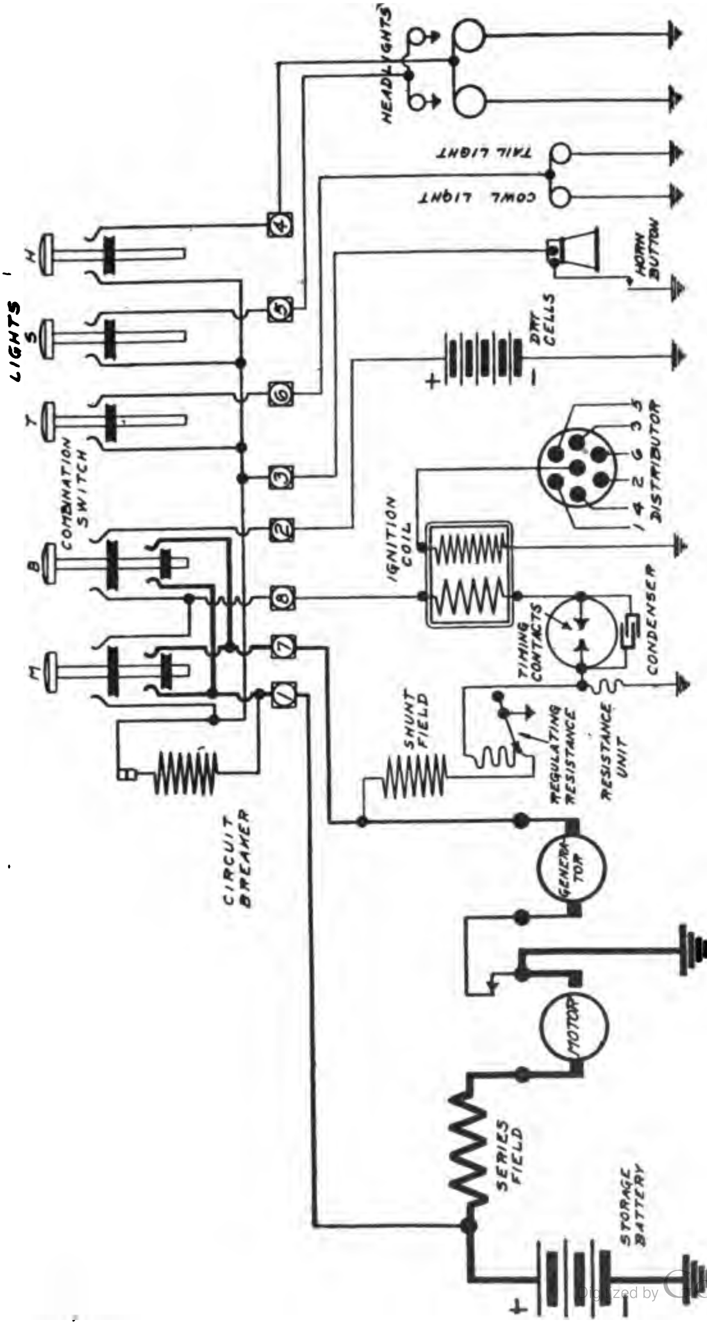


Fig. 208. Wiring Diagram for Delco Single-Unit System on the Auburn Six-40

unit and the timer, and the latter directly—are plain. But it also will be noted that a condenser is shunted around the sparking contacts of the timer, one side being connected to the contact terminating the positive side of the circuit, while the other is grounded. The function of a condenser here is to absorb the charge or surge of current due to the sudden opening of the contacts (breaking of the circuit) and to prevent the formation of an arc which would burn the contact points away rapidly. Badly pitted or burned contact points accordingly are an indication that the condenser has broken down or become disconnected from the circuit. This also will be evident from the excessive sparking at these contacts when the engine is running. The secondary winding of the coil is grounded directly. At the right-hand end of the diagram is seen the independent circuit of the dry-cell battery for emergency use in starting. The current from this battery passes through a relay coil the contact points of which are also provided with a condenser for the purpose already explained.

Auburn-Delco Type. The wiring diagram of the Delco lighting, starting, and ignition system of the Auburn, Model 6-40, Fig. 208, is more completely shown than the one to which reference was made above, in that all the switching connections are indicated and the lamp circuits have been carried out. Examination will also show that it differs in other respects as well. For example, instead of a bucking-coil type of regulator winding, the generator output is controlled through a variable resistance in the shunt-field circuit, the amount of resistance increasing with the speed. As the current through the shunt coil decreases with the increase in resistance, the fields are weakened and the generator output falls off.

Instead of the usual magneto-and-battery switch a special form of combination switch is shown in this wiring diagram which controls two circuits simultaneously, the generator-battery circuit and the circuit breaker-ignition coil circuit. These are discussed further in the main Delco section.

Diagram for Two-Wire System

Chevrolet-Auto-Lite Type. The wiring diagrams already explained are what are known as "single-wire" or grounded systems, there being but a single wire connecting any piece of apparatus to the source of current supply, the return side of the circuit being through the frame of the car. While usually referred to as the "return" side of the circuit, the steel sections forming the frame of the car may be utilized for either the positive or negative side.

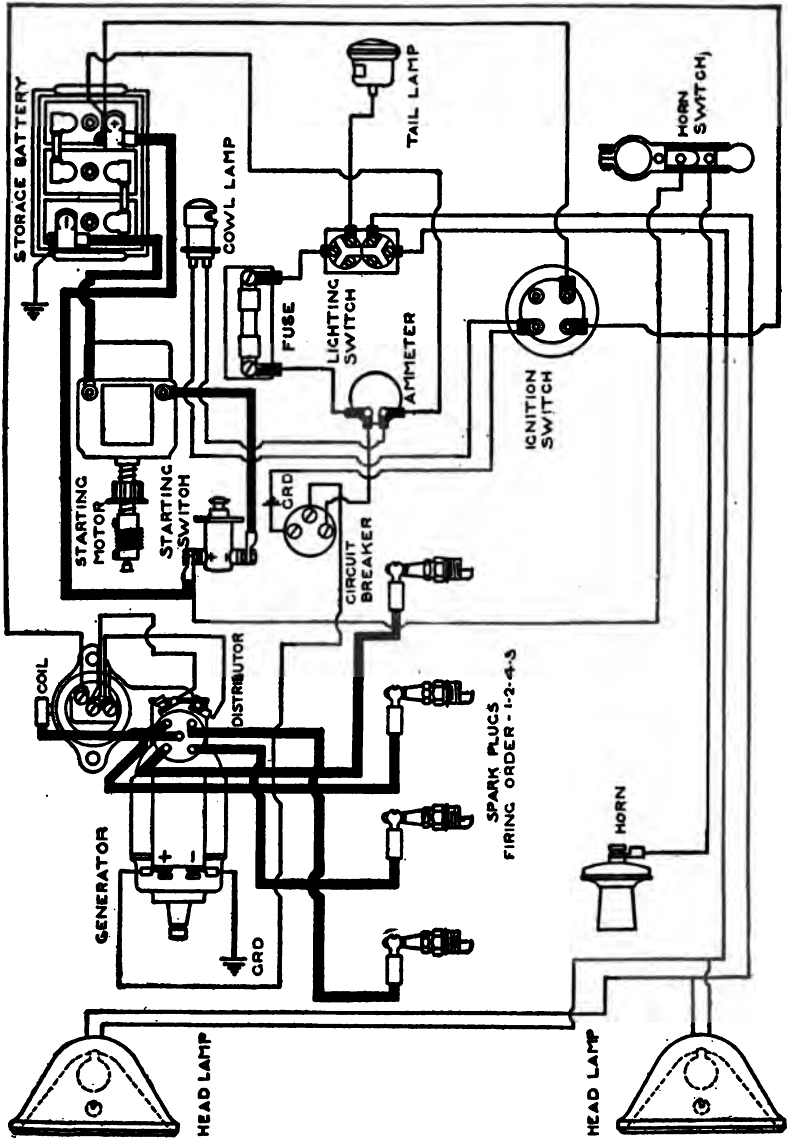


Fig. 209. Wiring Diagram for Auto-Lite System on Chevrolet (Royal Mail and Baby Grand Models) Showing Two-Wire Connections

The wiring diagram, Fig. 209, which is that of the Auto-Lite system as applied to the Chevrolet is of the two-wire type. With

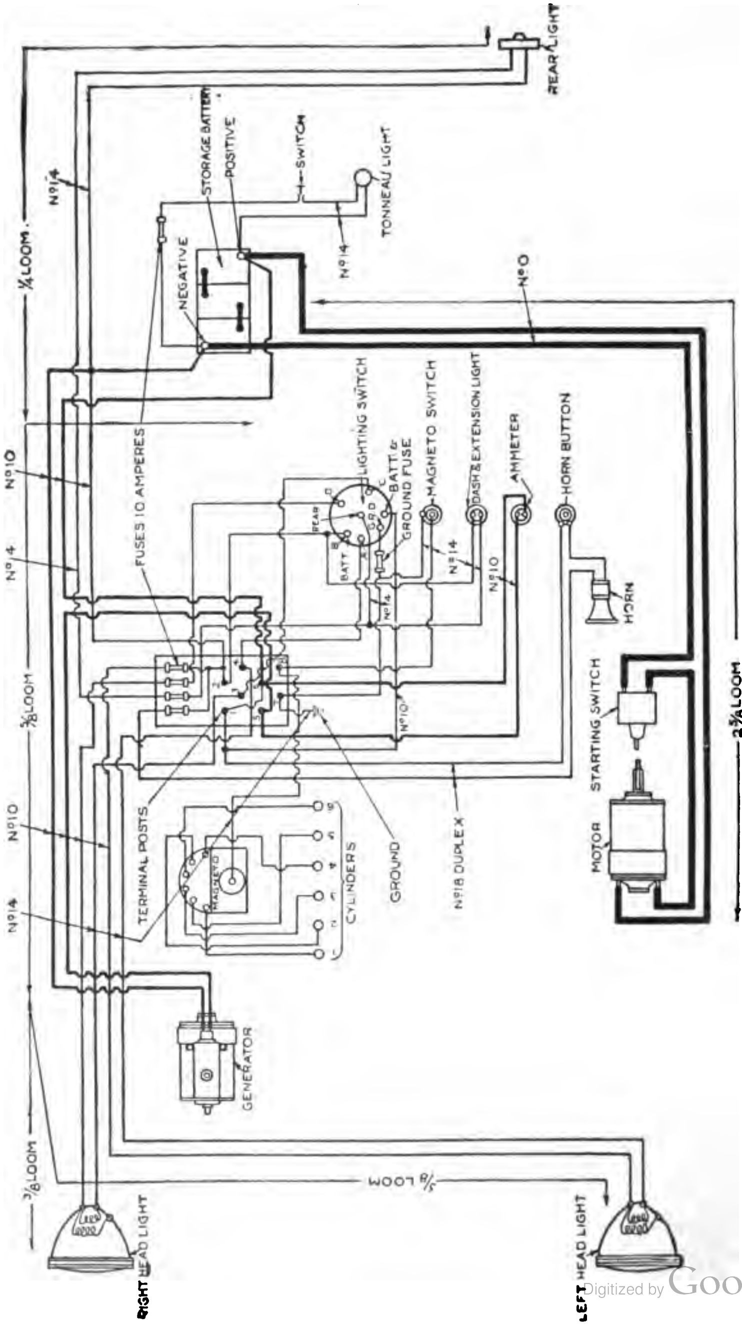


Fig. 210. Wiring Diagram for Bijur Two-Wire System on the Jeffery Chesterfield Six (1916 Model)

the exception of the ignition circuit, which is always grounded owing to the spark plugs completing the circuit by being screwed into the cylinder heads, it will be noted that two-wire connections are made. The ignition circuits are completed by a ground at the battery for the starting current, and by another at the generator for the current when running. The circuit breaker is also grounded.

Jeffery-Bijur Type. The two-wire system of the Bijur as installed on the Jeffery Chesterfield Six is shown in Fig. 210. All lighting circuits are fused and there is also a fuse in the ground connection for the ignition. The numbers referring to the various circuits indicate the proper size of wire used in each circuit. This is an important item in every starting and lighting system, as, where any wires have to be replaced owing to mechanical or electrical injury, they must always be replaced with wire of the same size and character of insulation, as otherwise, further and more serious trouble is apt to follow. Thus, for the starting circuit No. 0 (Brown & Sharpe gage) cable is employed; for the charging circuit between the generator and battery No. 10; for the lighting circuits No. 14, which is the size ordinarily employed for incandescent-lamp circuits in house wiring; and for the horn No. 18. "Duplex" in this connection means that both wires of the circuit are enclosed in the same braided insulation. "Loom" is tubular fireproof insulation through which the wires are passed to afford further protection, and the sizes vary in accordance with the size of the wires.

USE OF PROTECTIVE AND TESTING DEVICES

Circuit Breaker. This is a protective device, the theory of which will be clear at once upon referring back to the explanation of an electromagnet in the introductory chapter. It consists of an electromagnet with a movable armature adapted to open the circuit by its movement, the latter being controlled in turn by the amount of current flowing in the circuit.

By referring back to the diagram, Fig. 208, and noting the particular function of the circuit breaker, an excellent example of the value of ability to trace wiring diagrams at a glance can be shown. Assume that when the button *M* of the combination switch, Fig. 212, is pulled out, the ignition fails to work. An examination of the diagram shows that when *M* is pulled out, its lower contact bridges the wires No. 1 and No. 7 connecting the generator with the battery. At the same time its upper contact bridges a pair of terminals which insert the circuit breaker and the ignition coil on cable No. 8 in the circuit. Further examination of the ignition or lighting circuits shows that throwing on any one of these circuits includes the circuit breaker. The function of the latter is to prevent the discharge of the battery when the generator is standing idle or running too slowly to generate the necessary voltage to charge the battery. It also serves to protect the lamps, ignition coil, and horn from damage, in case any of the wires leading to these essentials should become grounded, and in this rôle takes the place of fuses and fuse block. As it requires 25 amperes to operate the circuit breaker in this particular instance, it is not affected by the normal operation of the lamps, ignition, or electric horn. But in the case of a short circuit or ground, the whole output of the battery would pass through the circuit breaker, moving its armature and breaking the contacts, which open the circuit. This cuts off the current and a spring brings the contacts together again, when the operation is repeated, causing the circuit breaker to vibrate and pass an intermittent current of comparatively small value. While it will not break the circuit on less than 25 amperes, it will continue to vibrate on a current of 3 to 4 amperes. Its continued vibration is an indication that there is a ground in one of its circuits. Hence, no attempt should be made to stop this action by tightening the spring of the circuit breaker, but by locating the ground.

Tracing for Grounds. This can best be done by a process of elimination in which a knowledge of the wiring diagram will come handy. Referring again to Fig. 208, if the circuit breaker operates when switch *M* of the combination is pulled out, it will be apparent that the ground is located in either the main generator-battery circuit, or the ignition-coil circuit, as it will be seen that the lower contact member of the switch throws the former in the circuit and the upper contact member throws the latter in the same circuit with the circuit breaker. If pulling out *M* does not set the circuit breaker operating, but pulling out *T* does, this would indicate a ground in the circuit of the tail and cowl lights, while the operation of the circuit breaker on pulling out either *S* or *H*, would indicate that the ground was located in the wiring of either the side lights or the headlights depending on which switch caused the circuit breaker to respond. The combination switch *B* serves to connect the generator and storage battery in the circuit, the same as *M*, but it also includes the 5-cell dry battery in the ignition circuit. It will be noted that the distributor has six spark plug leads, indicating a 6-cylinder engine, also that the connection of the ignition timer in the circuit is somewhat different from the previous diagram, Fig. 207, in which it is on a branch circuit of the storage battery, whereas in this instance it is also in the generator circuit.

Having determined the particular circuit in which the fault lies it is next necessary to narrow it down to exactly the defection that is causing the ground. For work of this nature nothing handier can be devised than the simple testing set which is described later and which may be assembled at nominal expense.

Fuses. The lighting circuits of many cars are provided with fuses, designed to protect the battery. These fuses are usually of the enclosed type, consisting of a glass tube with brass caps at each end to which the fusible wire is connected, as shown in Fig. 211, Usually when a fuse "blows", due to excessive current caused by a ground or "short", the wire melts entirely and this will be visible. But at times it will simply melt at the soldered connection and not show any fault. In beginning a test it is well to go over the fuses first, holding one of the test points of the lamp circuit on one end of the fuse and touching the opposite end of the fuse with the second test point. Failure of the lamp to light will indicate the defective fuse. On systems employing a circuit breaker as shown in the wiring diagram, Fig. 208, no fuses are necessary as the circuit breaker serves the same purpose and also gives an audible signal of trouble by its buzzing. Upon finding an open circuit where one is supposed to exist as shown on the wiring diagram, it is always well to verify this by again testing the trouble lamp itself before beginning to tear anything out. The rough handling to which such a lamp is subjected frequently causes the filament to break.

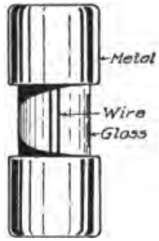


Fig. 211. Typical Fuse

If immediately upon being replaced, a fuse again blows, it may indicate that one of the lamp circuits of the car is short-circuited or the lamp on that circuit is defective, having become short-circuited, the remedy being a new bulb. In some systems, fuses are used in other circuits, as in the case of the Bosch-Rushmore in which there is a fuse on the switch block to protect the main shunt winding of the generator. The blowing of this fuse indicates a broken battery connection, such as a loose or broken terminal or a corroded battery connection on the cells themselves.

Handy Test Set. Take a porcelain base socket, screw it to a piece of board to form a base. Connect one side of this lamp socket to a standard screw plug. Procure two pieces of brass or steel rod and file or grind them to a long tapering point. These rods should be about 6 inches long and tapering half their length to a sharp point. Connect the other side of the lamp socket to one of these points and connect the second point to the other terminal of the screw plug. Ordinary lamp cord can be used for the connections. For fastening to the test points it should be bared for several inches, wrapped solidly around the metal rods at their blunt ends, and

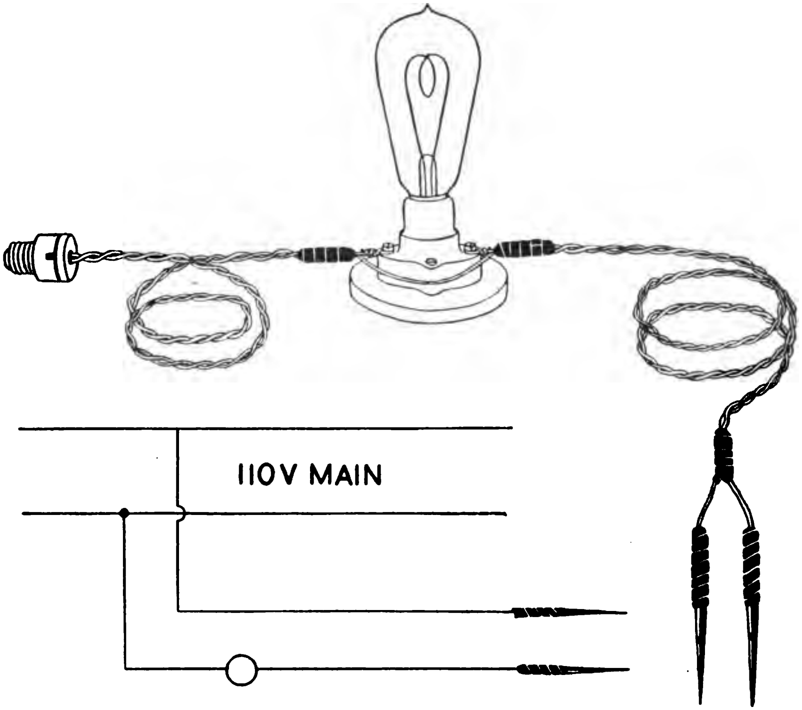


Fig. 212. Handy Testing Set

soldered fast in place. The joints should be heavily wrapped with tape or covered with other insulating material to form a handle, as shown in the illustration, Fig. 212, As shown by the diagram forming part of this illustration, it will be seen that the lamp is in series with one of the points, but that when the circuit is closed by bringing the two points together, the lamp is in multiple with the main circuit. The lamp should be of the carbon-filament type owing to its greater durability. As a lamp of this type of 16 c-p. only consumes a little over 50 watts at 110 volts, or approximately half an ampere of current, there is no danger of injuring any of the apparatus on the automobile through its use. Sufficient cord should be allowed on either side of the lamp to permit of connecting it up with the outlet conveniently.

In using this test outfit, the two test points are pressed on places between which no current should pass, and if the lamp lights it indicates that there is a ground between those points. For example, in Fig. 208, if there were a ground between the generator and the switch so that no current reached the latter, the lamp would not light when the test points were placed on terminals 1 and 7 of the diagram, the generator then being in operation. But a little searching along this circuit would soon show where it was grounded, thus making it easy to locate the break or ground. Fig. 213 is a graphic illustration of a ground causing a short circuit, due to worn insulation. Much more satisfactory results can be obtained with a test set of this nature than with either an expensive hand ringing magneto test set, or with a set consisting of a bell or buzzer and a few dry cells. The former is unnecessarily expensive for the purpose while the latter has not sufficient potential to force the current through grounds or breaks that present too great a resistance, whereas the higher voltage of the lamp test set will cause it to give an indication where the battery set would not. With the aid of such a set, every circuit shown on even the most complicated of

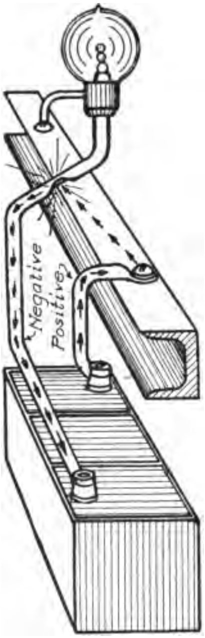


Fig. 213. Diagram of Ground or Short Circuit
Courtesy of Gray and Davis Company

wiring diagrams can be tested in fifteen to twenty minutes, maybe less, depending upon how accessible the connections of the various circuits happen to be.

If preferred, owing to greater convenience, a 6-volt lamp can be used in the socket of the test set and current from the car battery can be utilized for testing. In case the car happens to have either a 12-volt or a 24-volt system, connect lamp terminals to but three of the cells. Should the lamp not light to full incandescence it will indicate a weak battery. Full directions for the care of storage batteries are given in the résumé in Questions and Answers, and also in the article on Electric Automobiles. In case the battery does not respond to any of the ordinary methods of treatment given there, it will usually be found preferable to refer it to the nearest service station of the battery manufacturer. This is particularly the case where after refilling with distilled water to the proper level and slowly recharging, the battery does not increase in voltage and specific gravity reading with the hydrometer.

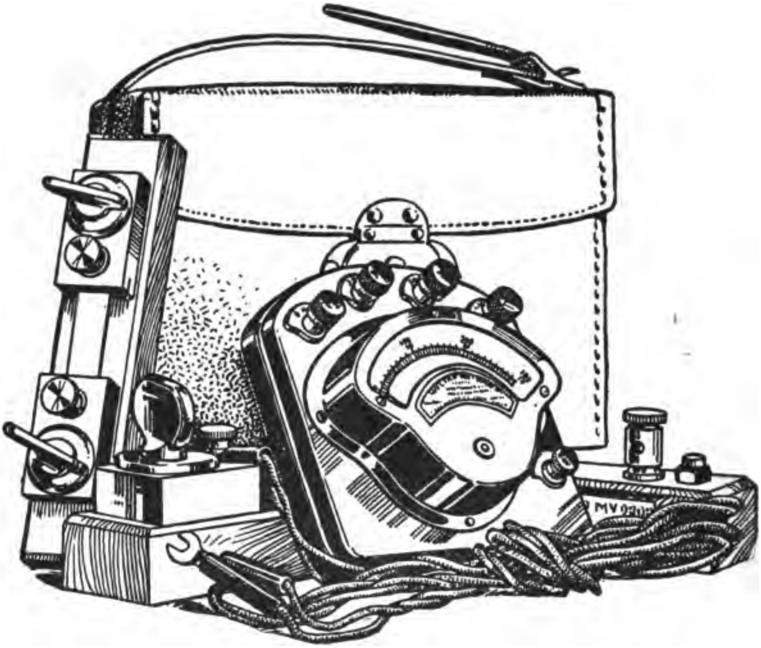


Fig. 214. Portable Combination Volt-Ammeter for Testing

Always Test the Lamp. Whether a standard 110-volt lamp or one of the 6-volt type (for which an adapter may be necessary to fit the standard socket) is used, it is a good precaution always to test the lamp itself before going over the wiring on the car. This will avoid the necessity for blaming things generally after failing to find any circuit at all—after fifteen miutes of trying everything on the car—due to the lamp having a broken filament or one of its connections having loosened up.

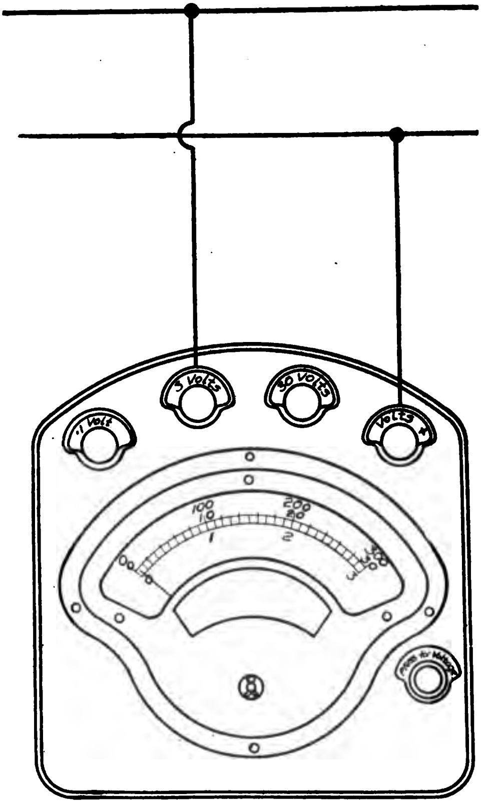


Fig. 215. Diagram Showing 3-Volt Scale Connected across a Circuit

Special Testing Instruments. For the garage that claims to be fully equipped to give all necessary attention to the electrical system of the modern car, something more than the simple lamp testing outfit is necessary. Portable volt-ammeters such as shown in Fig. 214 are made specially for this purpose. This is a Weston combination volt-ammeter, the voltmeter being provided with a 0–30, 0–3, and 0 to $\frac{1}{10}$ scales for making voltage tests, together with three shunts having a capacity of 0–300, 0–30, and 0–3 amperes, respectively, which are used in connection with the $\frac{1}{10}$-volt scale for making current measurements. A special set of calibrated leads for use with these shunts is also provided. With the aid of such an outfit, accurate tests can be made covering the condition and performance of every part of a starting-lighting and ignition installation. For example, a starting system may be otherwise in perfect working condition, but its operation causes such an excessive demand on the storage battery that the generator is not capable of keeping the latter sufficiently charged. Generator tests, which are described later, having failed to show anything wrong with the dynamo, a test of the starting motor, using the 0–300-ampere shunt of the instrument would doubtless show that an unnecessarily large amount of current was being demanded by the motor for its operation, and indicate a fault in the latter.

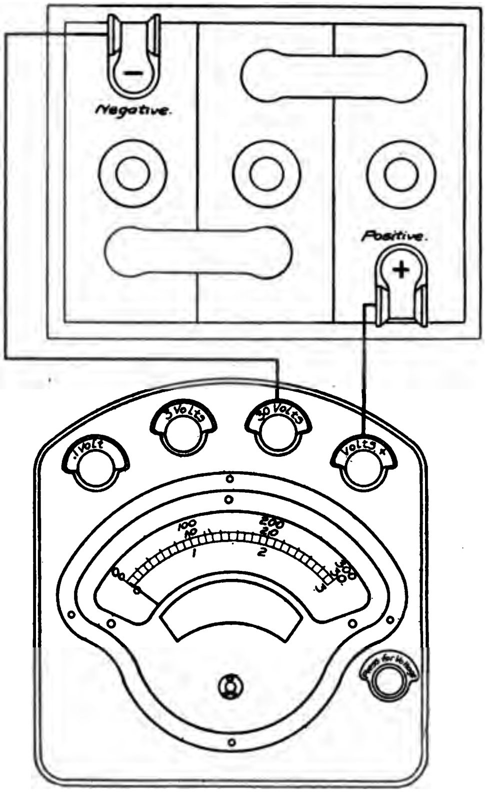


Fig. 216. Diagram Showing 30-Volt Scale Connected across Storage Battery Terminals

Voltage Tests. When the instrument is used as a voltmeter it is necessary to select the proper scale for the circuit, and if there is any doubt it is well to start with the 30-volt scale. For testing individual cells of the storage battery the 3-volt scale would naturally be used, while for testing the entire battery, the 30-volt scale would be the proper one to apply. The proper method of connecting the voltmeter to the circuit is shown by the diagrams, Figs. 215 and 216. It is necessary to connect the positive side of the meter to the positive side of the circuit and the other terminal to the negative. Where the polarity of the circuit is not known, this can be readily determined by a trial reading. If the pointer moves to the right, the connections are properly made; in case it moves to the left, it will be necessary to reverse the connections, which should be done at the circuit terminals and not at the meter, to avoid any accidental short circuits.

Ammeter Readings. When using the ammeter to determine the amount of current consumed by any of the apparatus, such as the starting motor or the lamps, it is necessary to first select the proper shunt. Should the value of the current to be measured be unknown, it is well always to start with the 300-ampere shunt

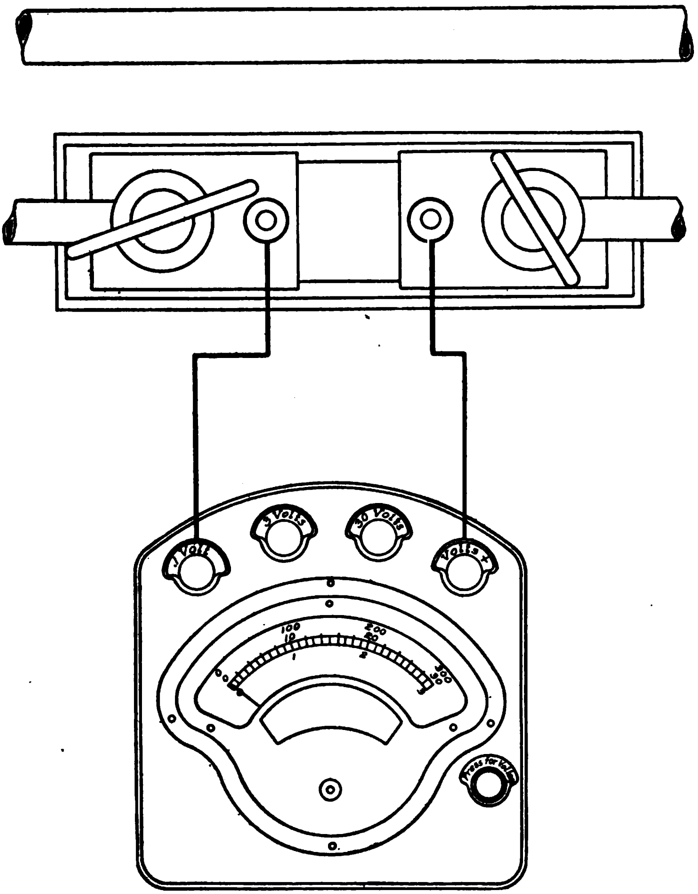


Fig. 217. Diagram Showing Method of Connecting Ammeter to 300-Ampere Shunt

and then insert the 30-ampere shunt in case the reading shows the current to be less than 30 amperes. These shunts are connected in the manner shown by Fig. 217, and as will be plain from this diagram, all shunts are connected in the circuit in a similar manner. The connections always remaining the same, it is only necessary to substitute the different shunts as required by the circuit to be measured. If the polarity be reversed, it is only necessary to shift the connections from the ammeter to the shunt which should be done at the latter, there being no necessity to change the connections of the shunt itself to the circuit. The 300-ampere shunt must always be used for measuring the starting current, as the latter will rarely have a value of less than 200 amperes when the switch is first closed owing to the necessity of exerting great power at first to overcome the inertia of the gasoline engine, particularly at a low temperature when the lubricating oil has become gummed. Cables of the same size as those employed on the starting-motor circuit of the car should be provided for connecting up the shunt to make the tests. The 30-ampere shunt is employed for measuring the charging current to the battery, while the 3-ampere shunt is used for the individual lighting circuits or for the primary ignition current.

In the following section, the various systems in general use are described in detail.

AUTO-LITE SYSTEM

Six-Volt; Two-Unit; Single Wire

Generator. Three types of generators are furnished. One has a permanent magnetic field and resembles a magneto but can be distinguished by its drive and governor, as well as the fact that it is fitted with a commutator and brushes instead of a contact

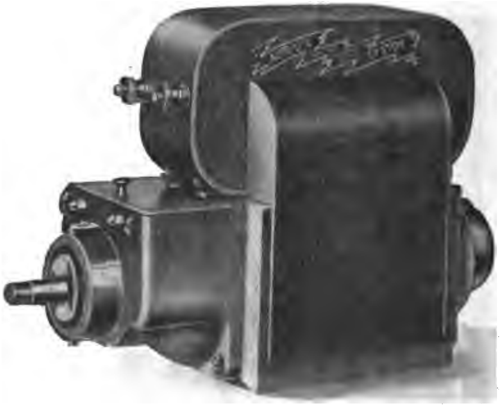


Fig. 218. Auto-Lite Generator of the Bipolar Type
Courtesy of Electric Auto-Lite Company, Toledo, Ohio

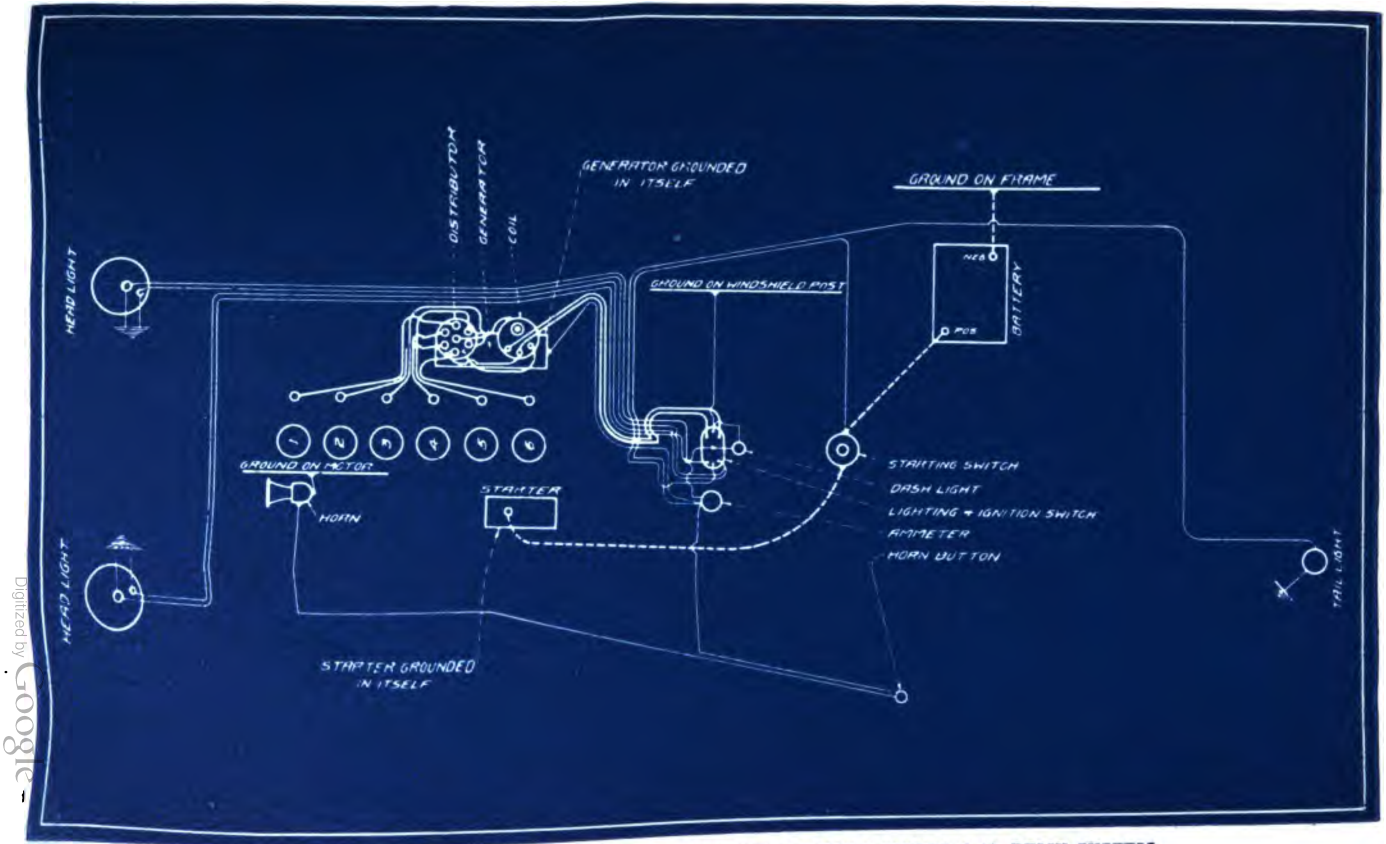


PLATE 1—WIRING DIAGRAM FOR ABBOTT-DETROIT 1917 CARS, MODEL 6-44, REMY SYSTEM

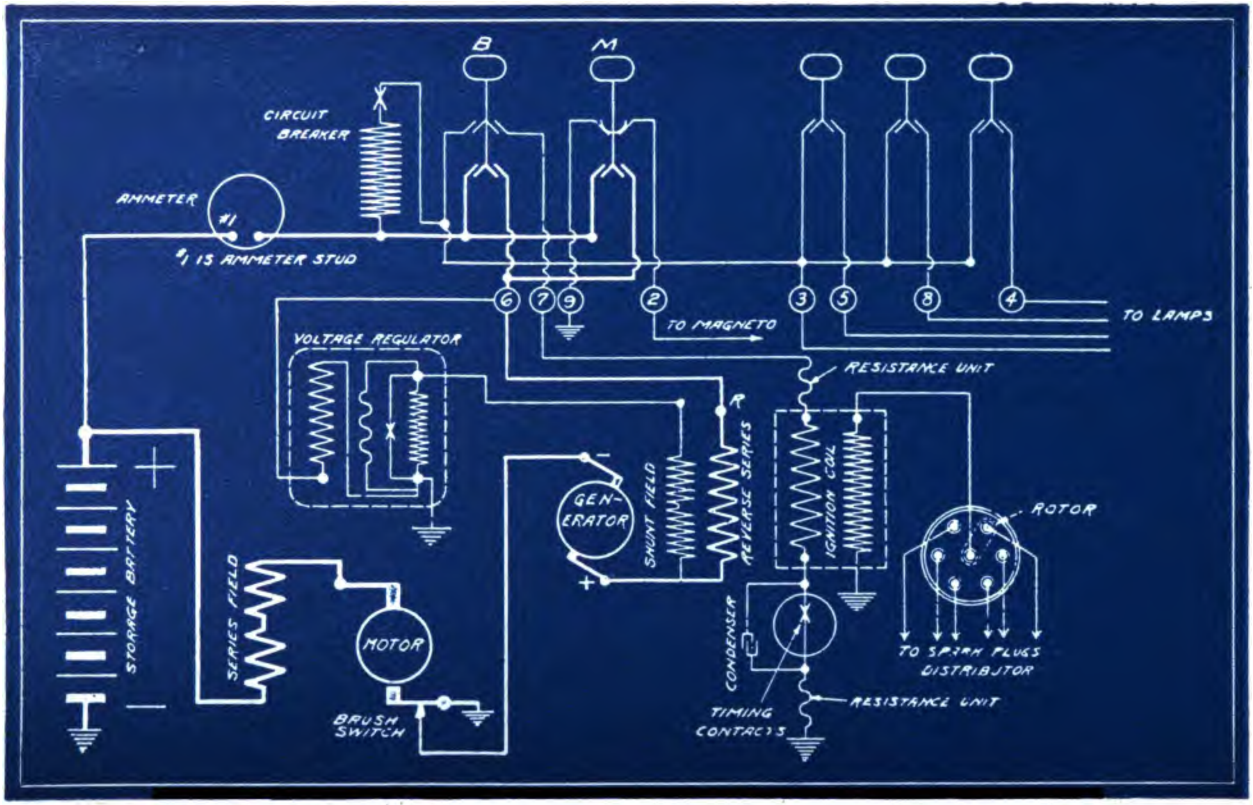


PLATE 2—DELCO STARTING AND LIGHTING WIRING DIAGRAM FOR AHRENS-FOX FIRE ENGINE

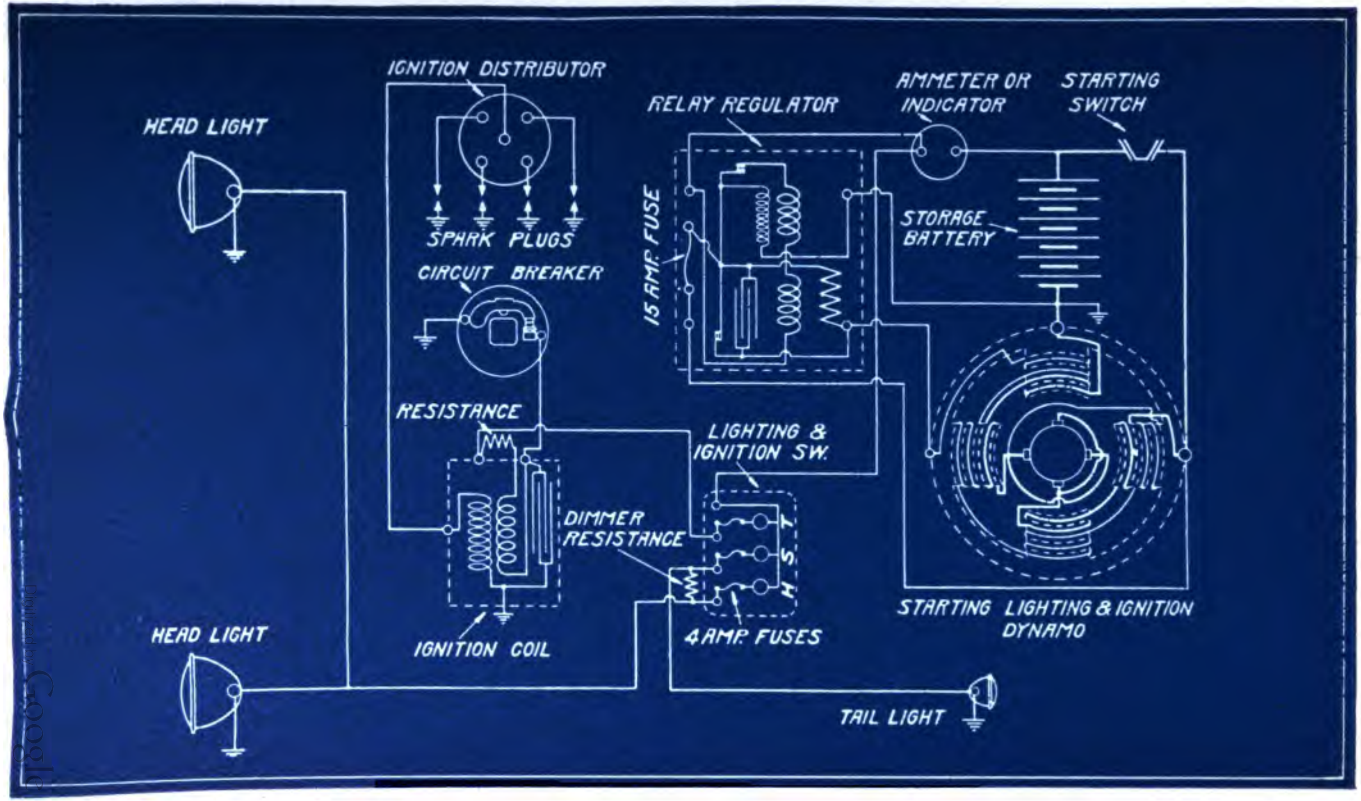


PLATE 3—REMY WIRING DIAGRAM FOR ALTER 1915-16 CARS

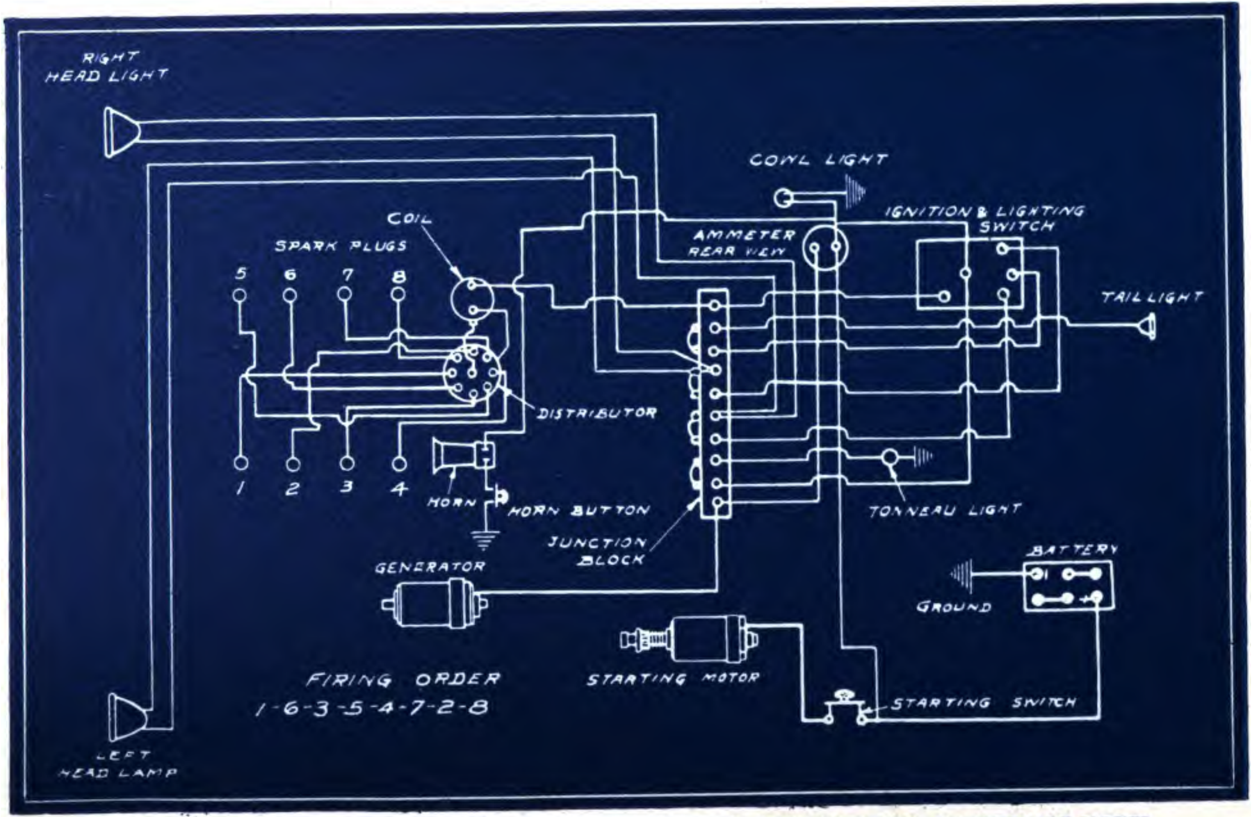


PLATE 4—BIJUR STARTING AND LIGHTING WIRING DIAGRAM ON APPERSON CARS, ANNIVERSARY MODEL

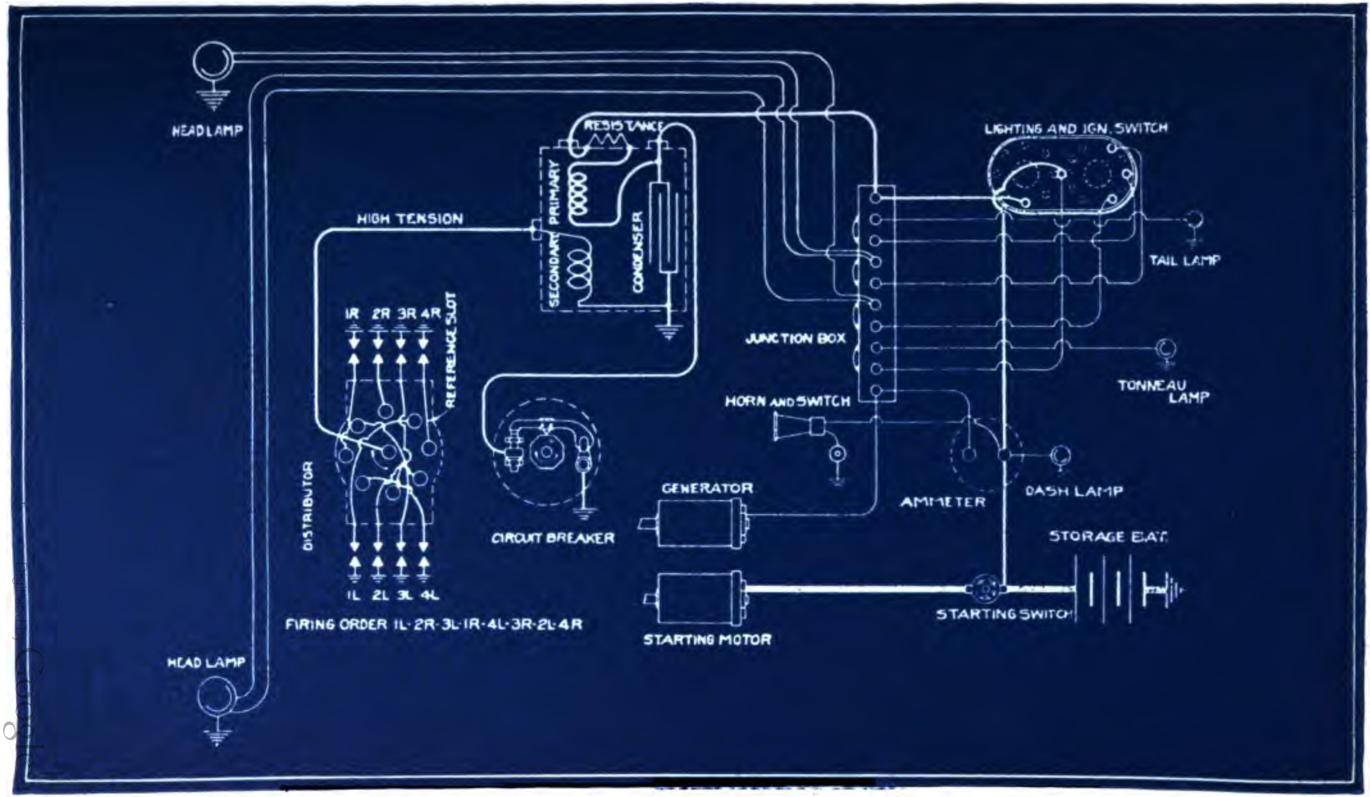


PLATE 8—WIRING DIAGRAM FOR APPERSON CARS, MODEL 8-18-A, REMY SYSTEM

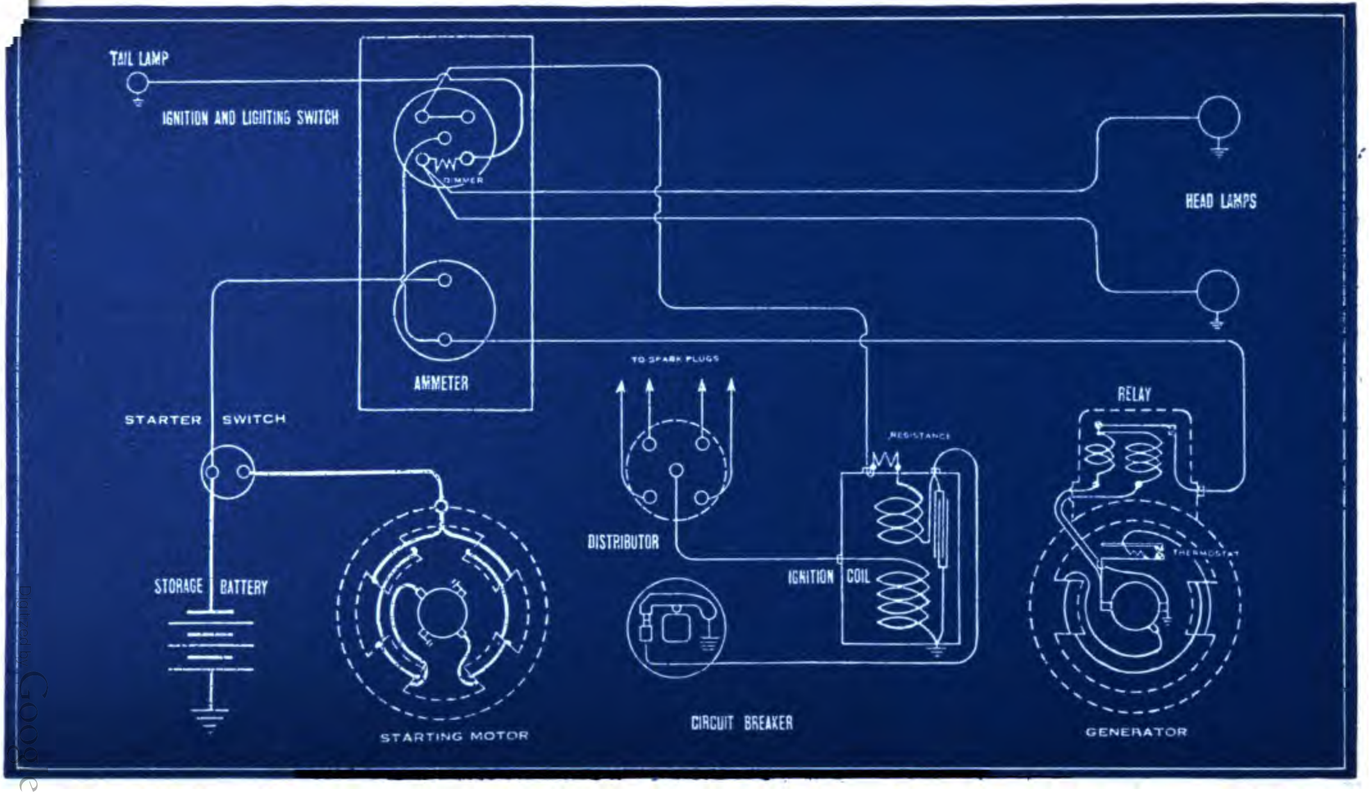


PLATE 6—REMY WIRING DIAGRAM FOR ATLAS THREE-QUARTER TON TRUCK

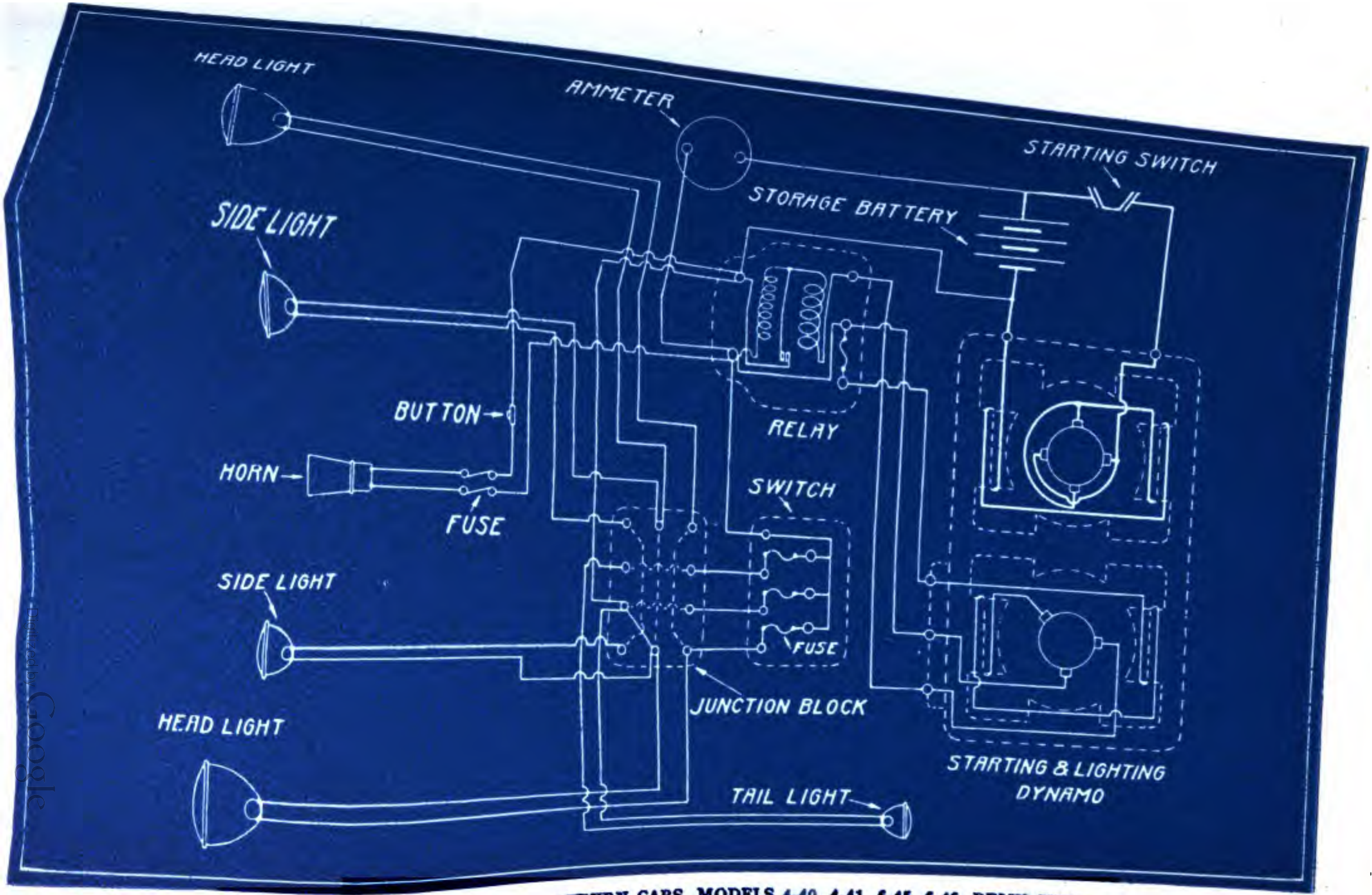


PLATE 7—WIRING DIAGRAM FOR AUBURN CARS, MODELS 4-40, 4-41, 6-45, 6-46, REMY SYSTEM

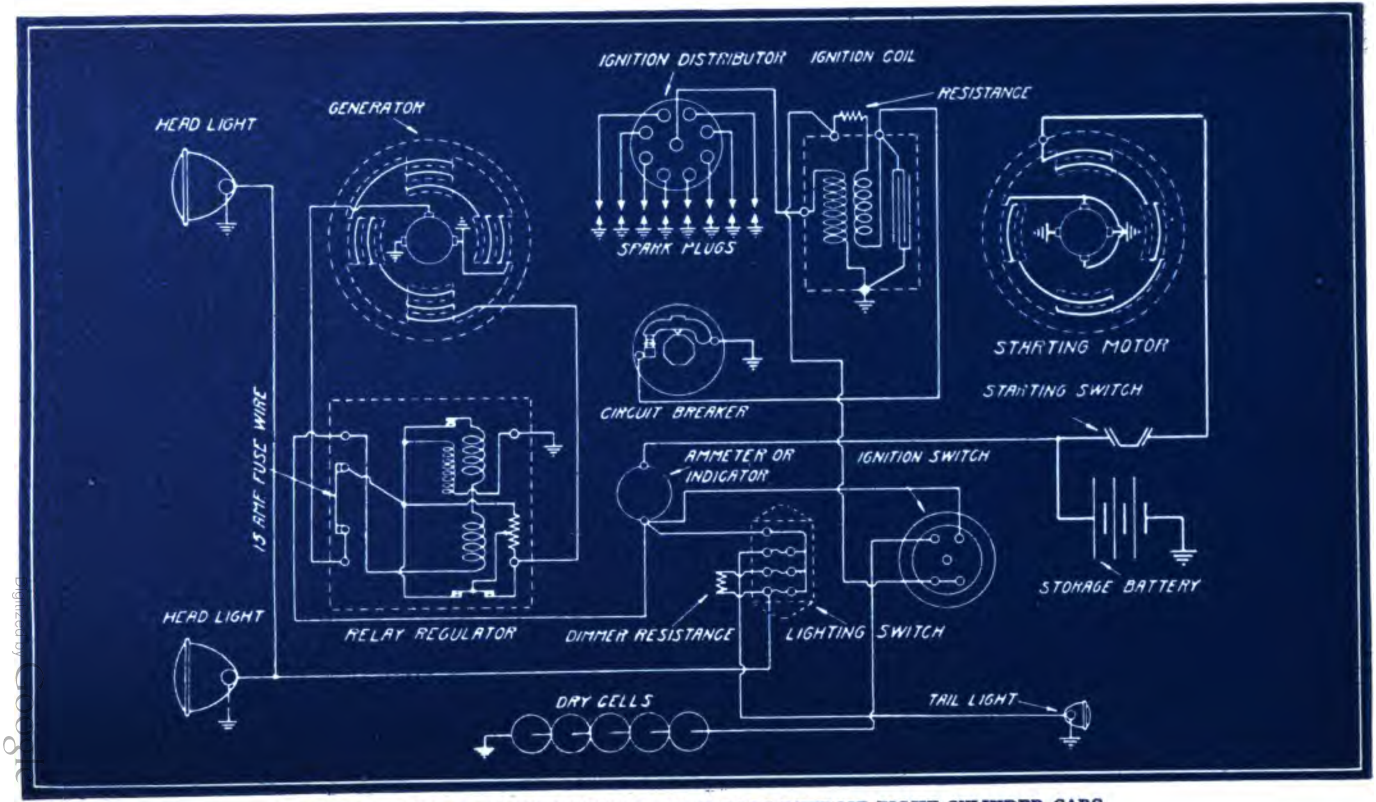
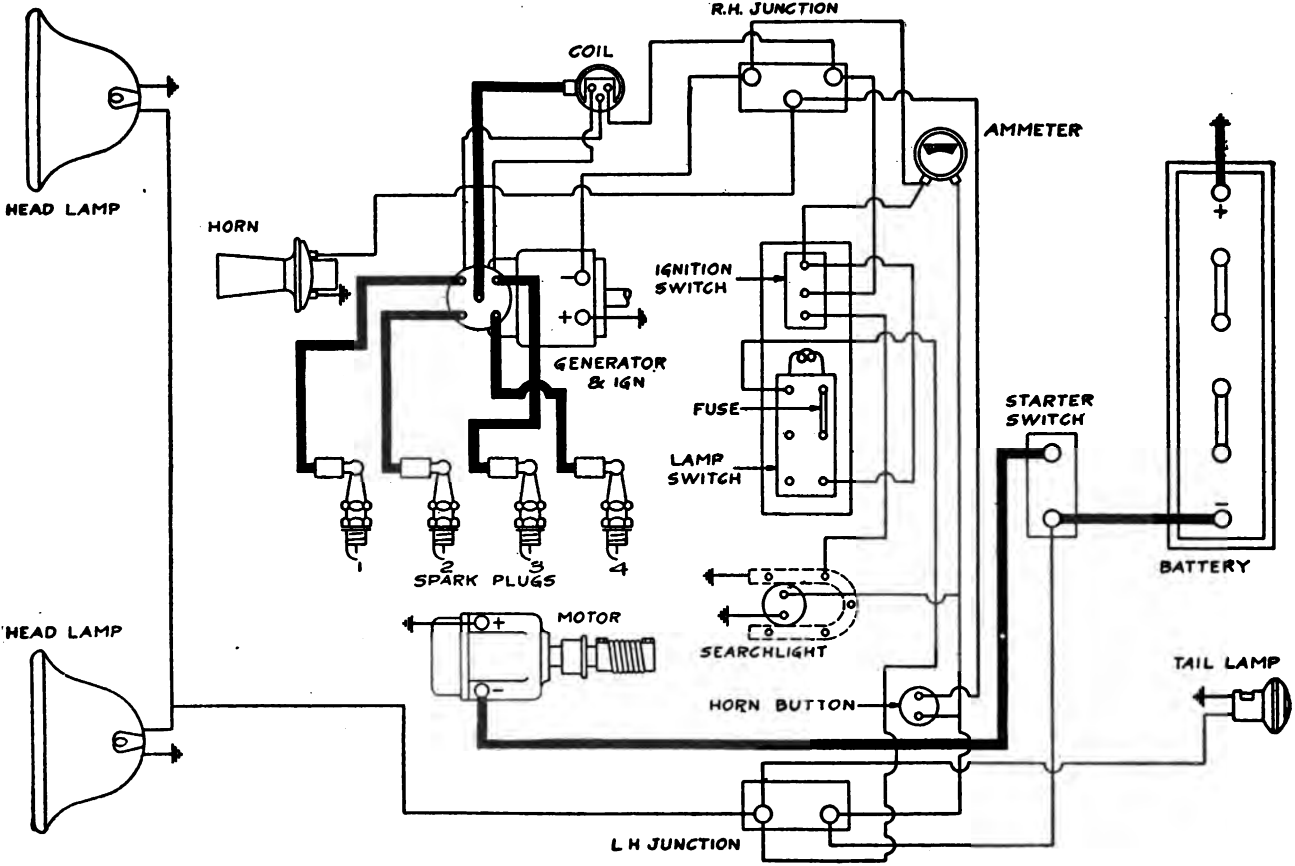
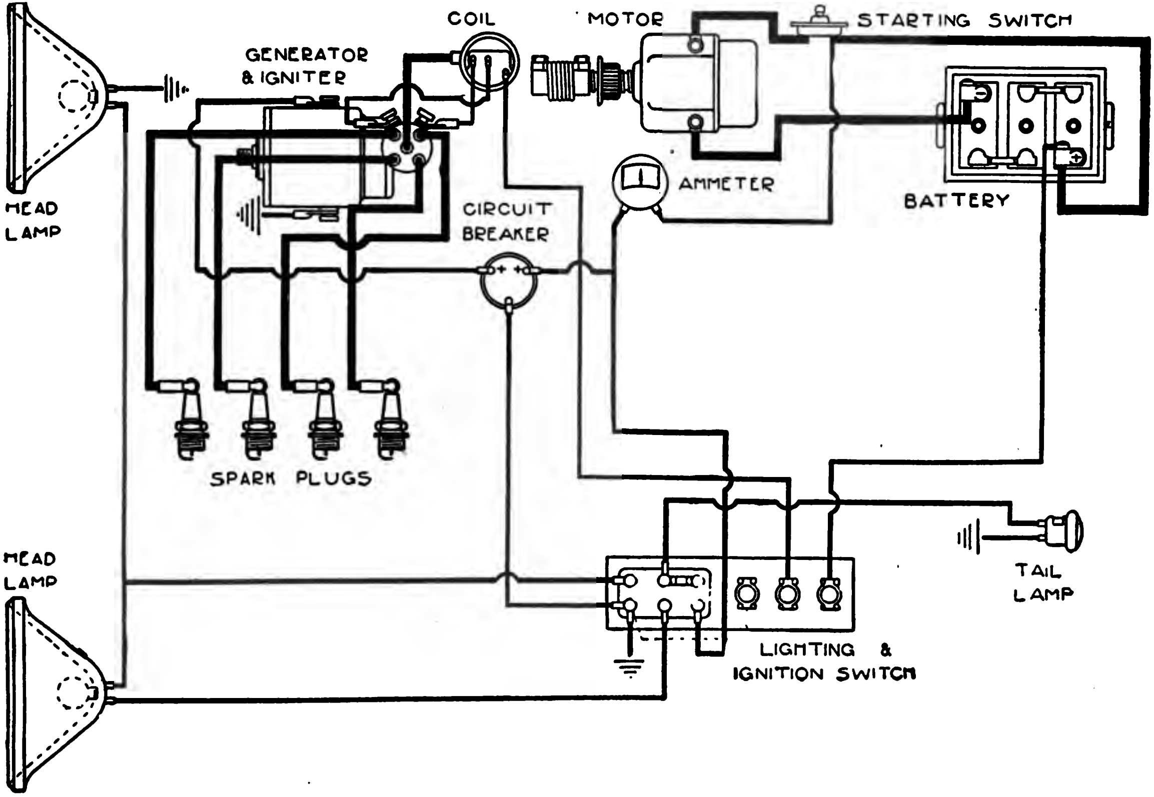


PLATE 8—REMY WIRING DIAGRAM FOR BRIGGS-DETROIT EIGHT-CYLINDER CARS



Auto-Lite Ignition, Starting, and Lighting System on Briscoe 1917 Motor Cars
Courtesy of Electric Auto-Lite Company, Toledo, Ohio



Auto-Lite Single-Wire Starting and Lighting System for Chevrolet 490 Cars
Courtesy of Electric Auto-Lite Company, Toledo, Ohio

breaker and distributor. It has been supplied chiefly for installation on cars which were not originally fitted with electric lighting and starting systems. The second is somewhat similar in design but has an excited field, the field magnets being of U-form and laminated; this type of generator is used on the Overland Model 82. There is a single field winding, as shown in Fig. 218. The third is a four-pole machine having two wound poles, usually termed *salient* poles and two *consequent* poles, which carry no windings. A diagrammatic section of this generator is shown in Fig. 219. The salient poles are those in the vertical plane while the consequent poles are horizontal. The diagram also shows the commutator, brushes, and the compound winding of the generator.

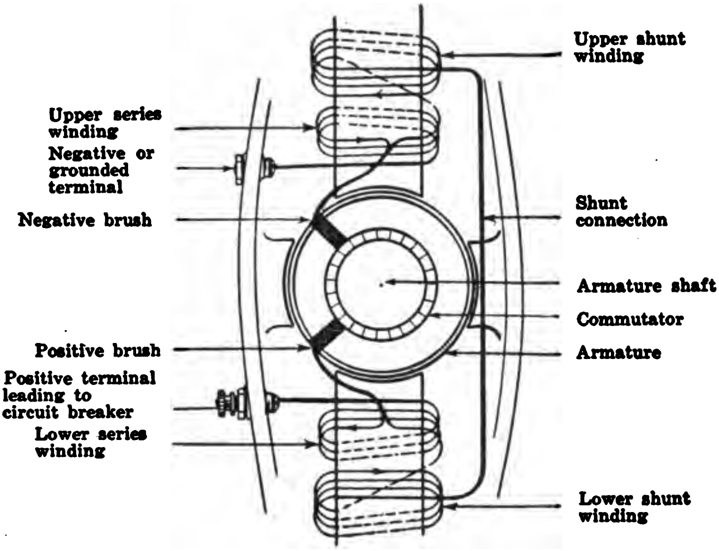


Fig. 219. Diagrammatic Section of Four-Pole Auto-Lite Generator

Regulation. The current output of the permanent-field type is regulated by a centrifugal governor; it should not drop below 10 amperes, nor exceed 12 amperes. Any falling off can be remedied frequently, simply by cleaning the governor out thoroughly with gasoline, allowing it to dry, and giving it a drop or two of light oil; if this does not increase the output sufficiently, the weights can be moved inward an eighth of an inch or more to decrease the pressure on the springs mounted in the governor arms, Fig. 220. This permits the generator to run at a higher speed. The regulation of the other type is *inherent* and is due to the series windings of the field being made in the reverse direction to that of the shunt windings, so that their polarity is reversed. This is commonly referred to as a *bucking coil,* also as a differential winding. As the speed increases, the magnetizing effect of the shunt coils is opposed by this bucking winding and thus kept within safe limits. This type of generator is used on the Overland Model 80 and Model 81, besides other cars.

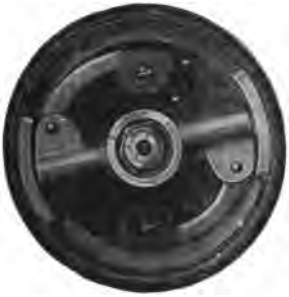


Fig. 220. Governor of Auto-Lite Permanent-Magnet Type Generator

Starting Motor. The starting motor is a series-wound multipolar type having four salient poles, Fig. 221 (used on Overland Model 80 and Model 81). In this type the switch is combined directly with the motor, being mounted in a housing at the left end as shown in Fig. 221. It is also fitted with a special locking device, the details of which are illustrated in the sectional view, Fig. 222. One of the buttons on the control board on the steering column closes the circuit of the solenoid shown in this illustration; this causes the plunger to lift and release what is known as the *gear-latch.* The shaft carrying the switch also serves to shift the pinion on the end of the starting-motor shaft into mesh with the flywheel gear. A later and more widely employed type of Auto-Lite starting motor is shown in Fig. 223; this is installed on the Overland Model 82 besides a number of other cars. It is known as the *Bendix drive* and is coming into very general use owing to its simplicity and its

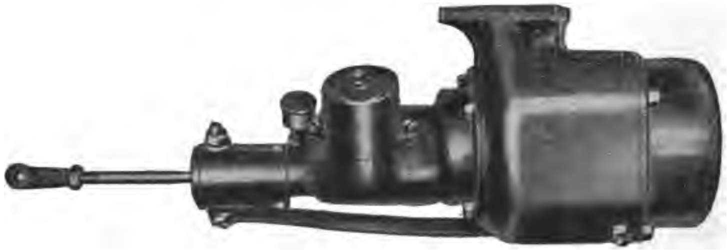
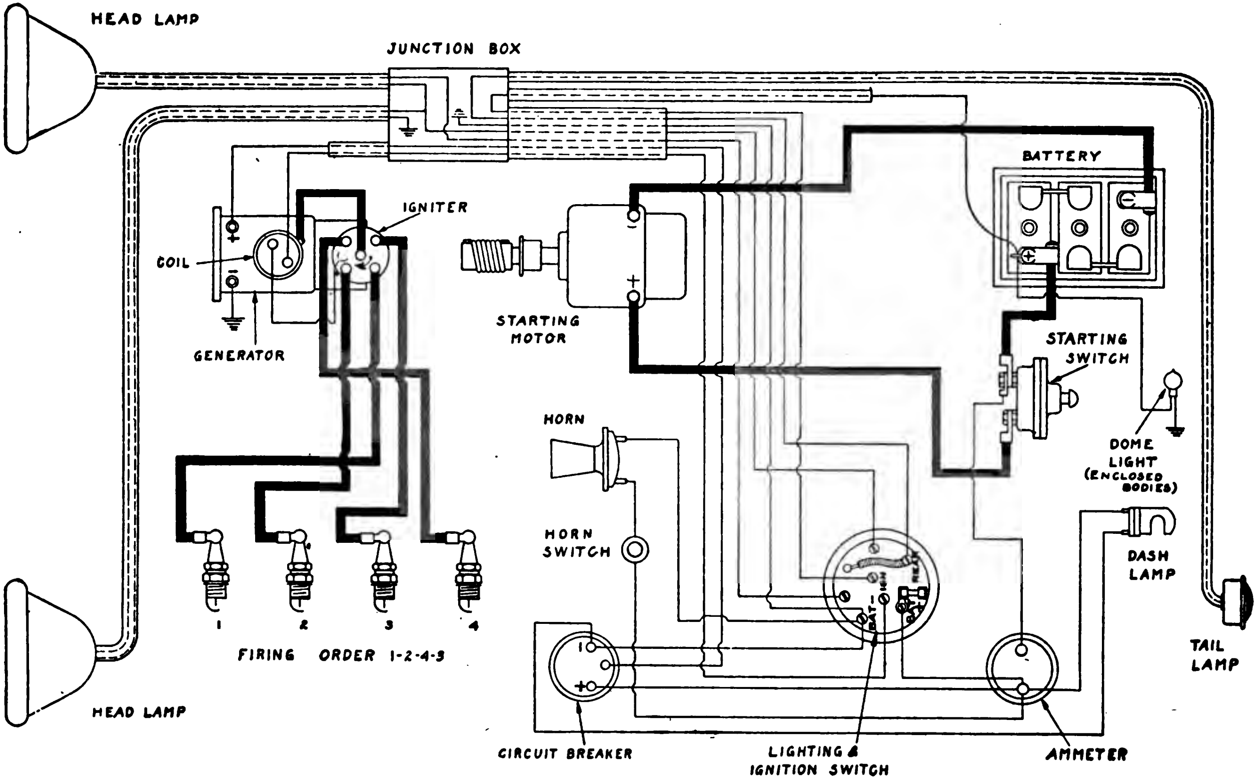
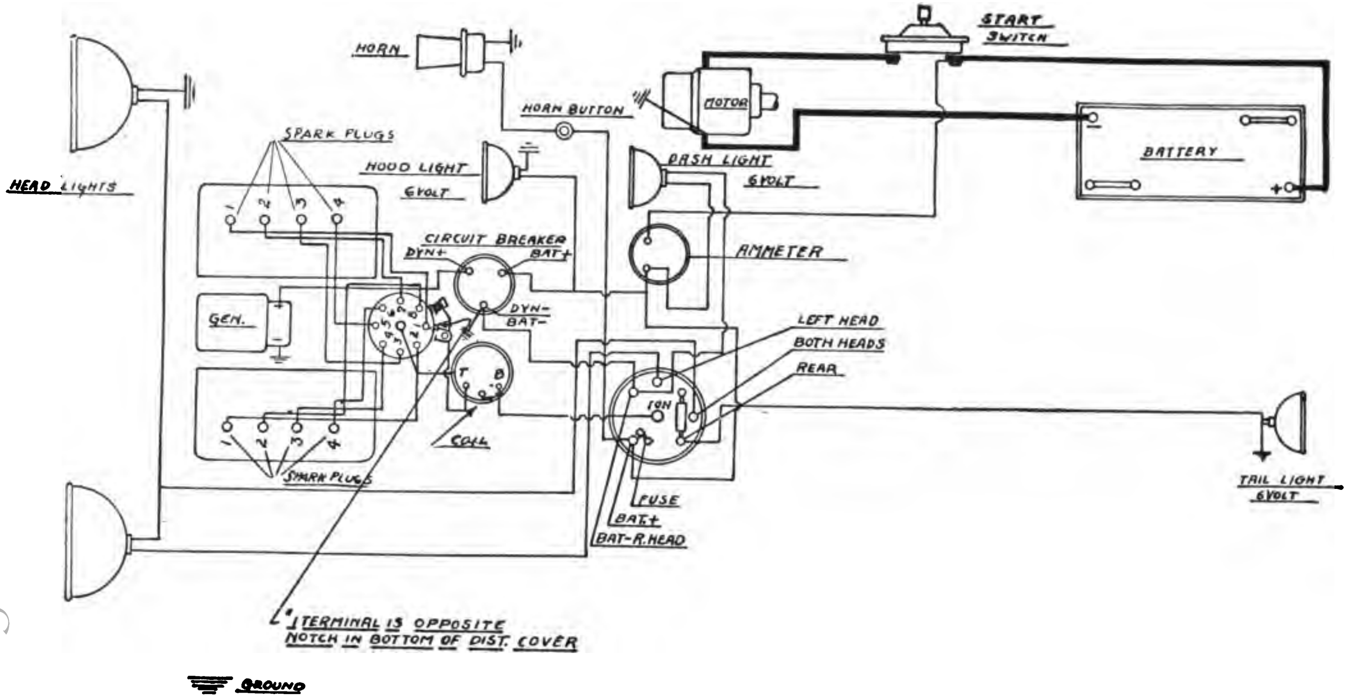


Fig. 221. Auto-Lite Starting Motor Used on Overland Models 80 and 81



Auto-Lite Starting and Lighting System on the Chevrolet, Model F
Courtesy of Electric Auto-Lite Company, Toledo, Ohio



Auto-Lite Starting and Lighting System on the Wolverine "349"
Courtesy of Jackson Automobile Company, Jackson, Michigan

automatic operation which eliminates the necessity for gear-shifting devices actuated by the switch, when operating the starting motor.

The armature shaft has a threaded extension provided with an outer bearing and carries a pinion. A weight is solidly attached to this pinion and the latter is loose enough on the shaft always to occupy the position shown with the weight underneath when the shaft is idle. The leading screw has a triple thread. On starting the electric motor the inertia of the weight causes it and the pinion

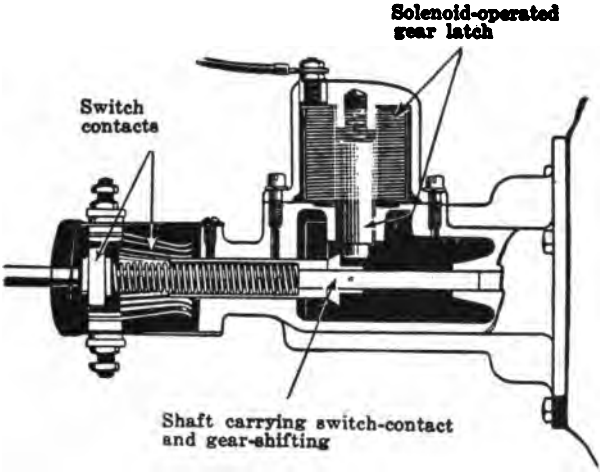

Solenoid-operated gear latch
Switch contacts
Shaft carrying switch-contact and gear-shifting

Fig. 222. Sectional View of Auto-Lite Starting Switch and Gear Release

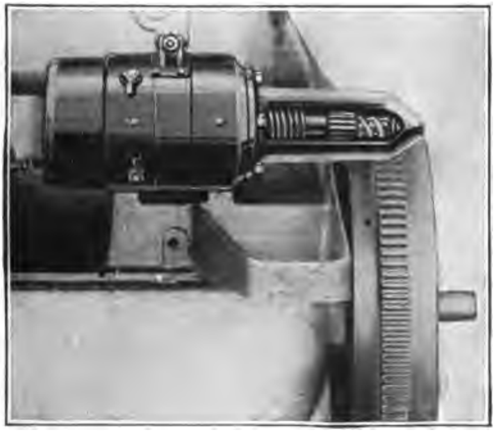


Fig. 223. Auto-Lite Starting Motor with Bendix Drive

to be carried along the shaft and into mesh with the gear on the flywheel in which relation it remains until the engine begins to run under its own power. This reverses the relation, the flywheel then driving instead of being driven, which automatically throws the pinion out of mesh. The coil spring shown is simply to take up the shock of starting and permits a slight play between the motor shaft and the threaded extension. Before the switch which is located on the footboards can be operated, a button on the control board must be pushed. This actuates a solenoid the plunger of which raises a latch, releasing the starting switch.

Battery Cut-out. The battery cut-out is shown in Fig. 224. As already explained, the majority of electric systems on the automobile must be provided with a cut-out to protect the battery when the generator speed falls below a certain point. It is frequently referred to as a *circuit breaker,* which it is in fact, though the circuit breaker is a protective device used for another purpose, as has been mentioned. The cut-out may be compared to a check valve in a water supply line between a pump and a tank; the pump can force water into the tank against its pressure but, regardless of how great this pressure becomes owing to the filling of the tank, the water cannot run back through the pump when the latter is idle.

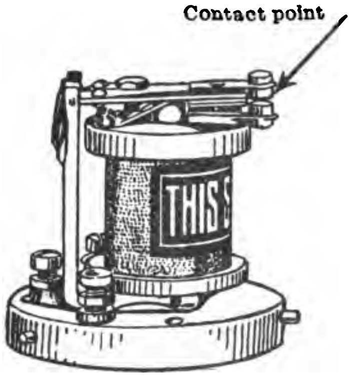
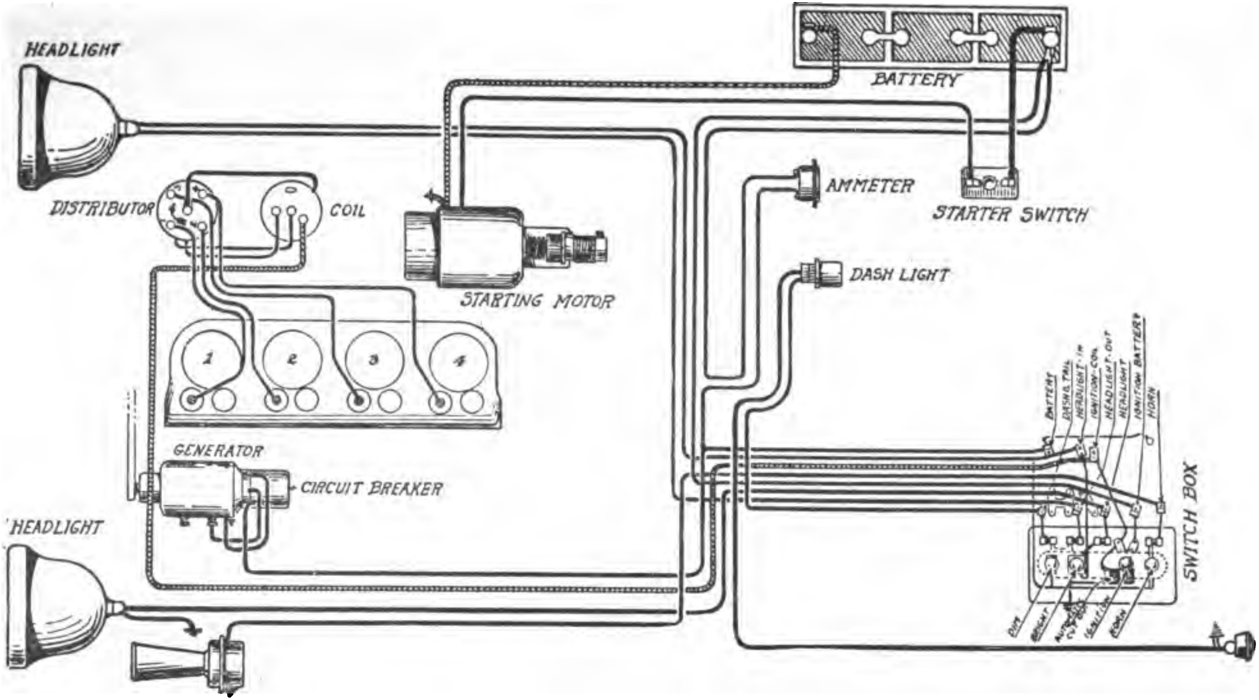
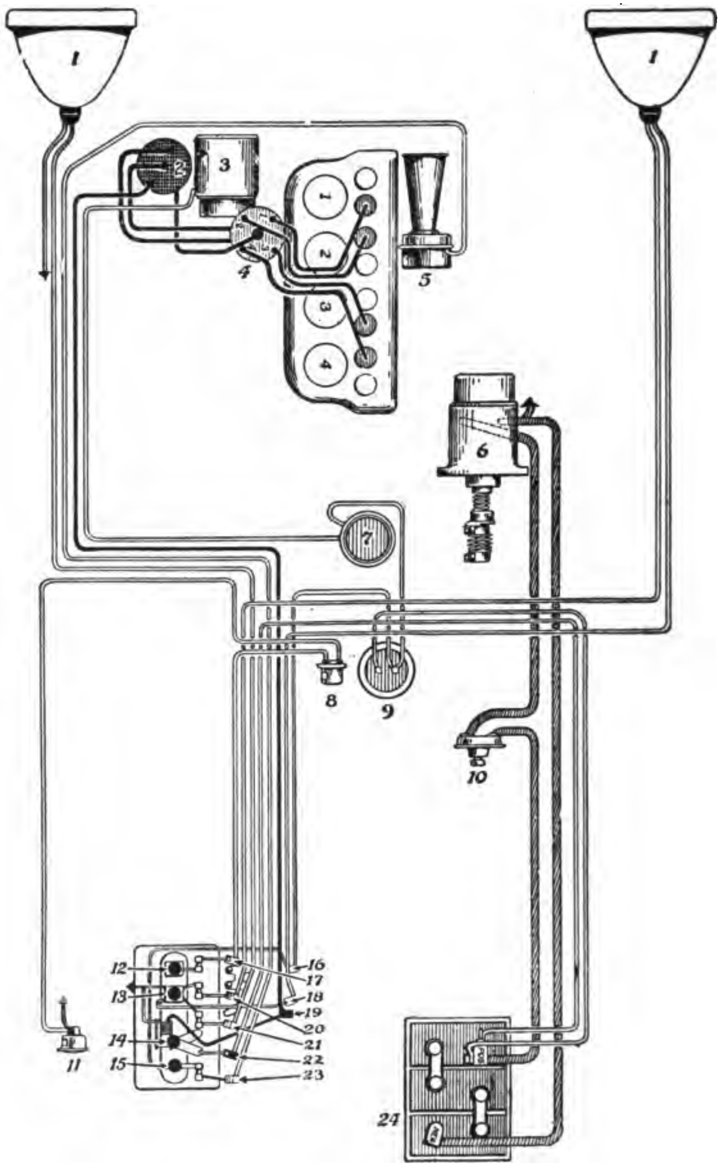


Fig. 224. Auto-Lite Battery Cut-Out (Circuit Breaker)

In principle, the battery cut-out is simply a magnetically operated switch. When the current passes through its winding the armature is attracted and brings a pair of contact points together. These will be seen at the upper right hand at the point of the arrow. In the best-grade apparatus, these points are of platinum or platinum and iridium as the latter is proof against oxidation as well as corrosion and resists pitting under the electrical current better than any other metal. As it costs more than gold, silver, which is next best for the purpose, is frequently employed. The cut-out in this case is set to close the circuit and allow the generator to charge the battery when the engine is driving the car at 7½ miles per hour, but



Auto-Lite Starting and Lighting System on the Overland, Models 85 and 85-B
Courtesy of The Willys-Overland Company, Toledo, Ohio



1. Head Lights
2. Coil
3. Generator
4. Distributor
5. Horn
6. Electric Starter
7. Circuit Breaker
8. Instrument Light
9. Ammeter
10. Starting Switch
11. Tail Light
12. Lights Dim
13. Lights Bright
14. Ignition Button
15. Horn Button
16. Battery
17. Dash and Tail
18. Head On
19. Ignition Coil
20. Head Out
21. Head Light
22. Ignition Battery
23. Horn
24. Battery

Auto-Lite Starting and Lighting System on Overland Light Fours, Model 90-4

Courtesy of The Willys-Overland Company, Toledo, Ohio

when the speed is dropping it does not open the circuit until it falls to 6 miles per hour. This is to prevent the cut-out from operating continuously when the car is running at its opening speed of 7½ miles. The battery, however, governs to a large extent the running speed at which the cut-out will operate. When fully charged, owing to the higher resistance thus presented, the cut-out does not close the circuit until the car is running at 10 to 12 miles per hour. In case the cut-out is removed from the car for any reason, the latter must not be operated until a short piece of bare copper wire is securely connected from the wire terminal post of the generator to one of the brass screws in the name plate.

Instruments. The instrument regularly supplied is a double-reading ammeter showing *charge* and *discharge* from 0 to 15 amperes. When lamps are off with car running at 10 miles per hour or over, it should indicate *charge.*

Wiring Diagram. The connections are practically the same, regardless of the type of starting motor installed, so that the following description will cover all three of the Overland models mentioned, Fig. 225. The ignition system is entirely independent of the starting and lighting system, although it appears on the diagram. The connections are as follows: Cable 12072, battery negative to motor terminal; cable 12073, battery positive to starting switch; wire 12236, starting switch to fuse block; wire 12066, fuse to positive ammeter terminal; wire 12066, negative ammeter terminal through fuse; wire 12069, to battery cut-out; wire 12068, generator positive terminal to cut-out. The battery negative is grounded at the end of cable 12072, while the cut-out is grounded to the frame through the wire 12906 and the generator is grounded at its negative terminal. This is an example of the frame of the car being employed for the negative side of the circuit, as compared with the Gray & Davis in which it is utilized for the positive side. While the ground connections of the lamps and horn are indicated as separate wires, in the case of the lamps the socket itself forms the ground connection. The location of the various fuses and the relation of the various essentials of the system will be clear upon tracing the diagram.

Instructions. While a car never comes into the shop to have its electrical equipment examined until some fault develops, and the man who has to locate the trouble seldom has occasion to run the car in ordinary service, still it is important that he should familiarize himself with the instructions issued to the owner, in order that he may know at a glance whether these instructions have been

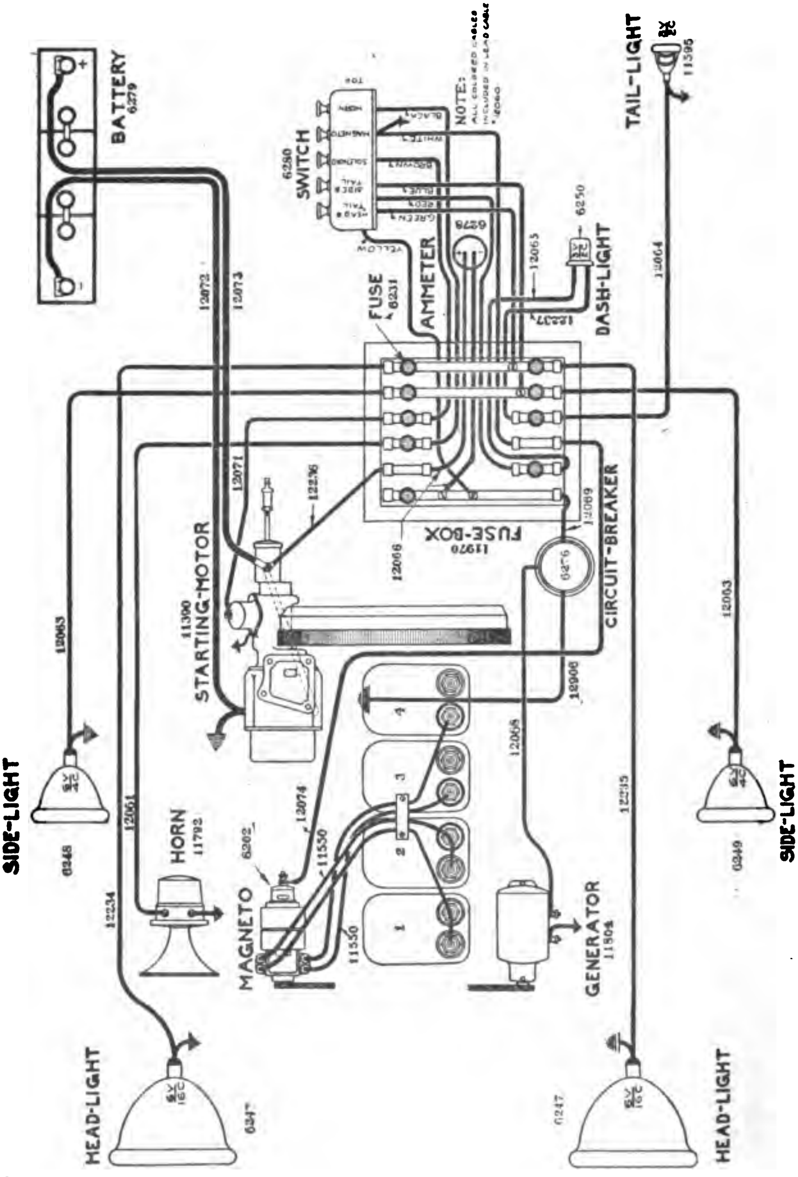


Fig. 225. Auto-Lite Wiring Diagram for Overland Cars

carried out or not. It is safe to say that more than half the troubles that arise with this equipment are due to failure to follow instructions in its use. The average motorist ordinarily pays little attention to the workings of the apparatus until it goes wrong and then he is helpless. There is, however, another type—the man who is given to tinkering. He is responsible for not a few of the problems that come into the garage, and familiarity with the manufacturer's instructions will assist in tracing the result of his efforts.

Chain Drive The silent-chain drive of the generator should be inspected occasionally and any slack taken up by loosening the screw which holds the generator on its bracket, and moving the generator over by means of the adjusting screw. The chain should be just slack enough to have no strain on its links when the engine is not running. Although the initial stretch of the chain is taken out at the factory by running it under load, these chains will continue to stretch slightly in service. After making the adjustment the holding screws should be re-tightened.

Commutator and Brushes. The commutator is the most vulnerable part of a direct-current machine. It should be examined first whenever there is any trouble with the generator, such as insufficient output of charging current, or with the starting motor, such as loss of power, the battery being in good condition. (No mention is made of battery instructions in this connection as the subject is fully dealt with in another volume, and in the summary following this section. The battery is, however, the cause of fully 80 per cent of all electrical-system troubles and neglect is at the root of most of these.)

The commutator is made accessible by the removal of a small plate—in this case, the name plate. If it is blackened and rough, the brushes first should be examined and trued up and the commutator should be smoothed down with fine sandpaper (never use emery cloth as it is metallic and will short-circuit the segments). The mica insulation should be carefully examined; if it is flush with the copper segments this is the cause of the roughened up brushes, and the mica should be undercut. Detailed instructions for smoothing the commutator, truing up the brushes and undercutting the mica insulation are given in connection with the Delco system. Any carbon dust from the brushes should be carefully blown out as this will tend to short-circuit the armature and field windings. See that the brush holders swing easily on the studs and that there is just enough spring tension on the brushes to make good contact on the commutator. Too much tension will cause unnecessary heating and wear of the commutator and brushes. Keep the commutator and brush chamber free from dirt and grease. Never replace brushes with any but those supplied by the manufacturer. See that the brush holders are well insulated from their supports, replacing any of the insulating plates, bushings, or washers that may have become damaged. Should the battery or generator be disconnected do not run the engine until they are again connected. Should it be necessary to do so, connect a short piece of bare copper wire from the terminal of the generator to one of the brass screws in the name plate.

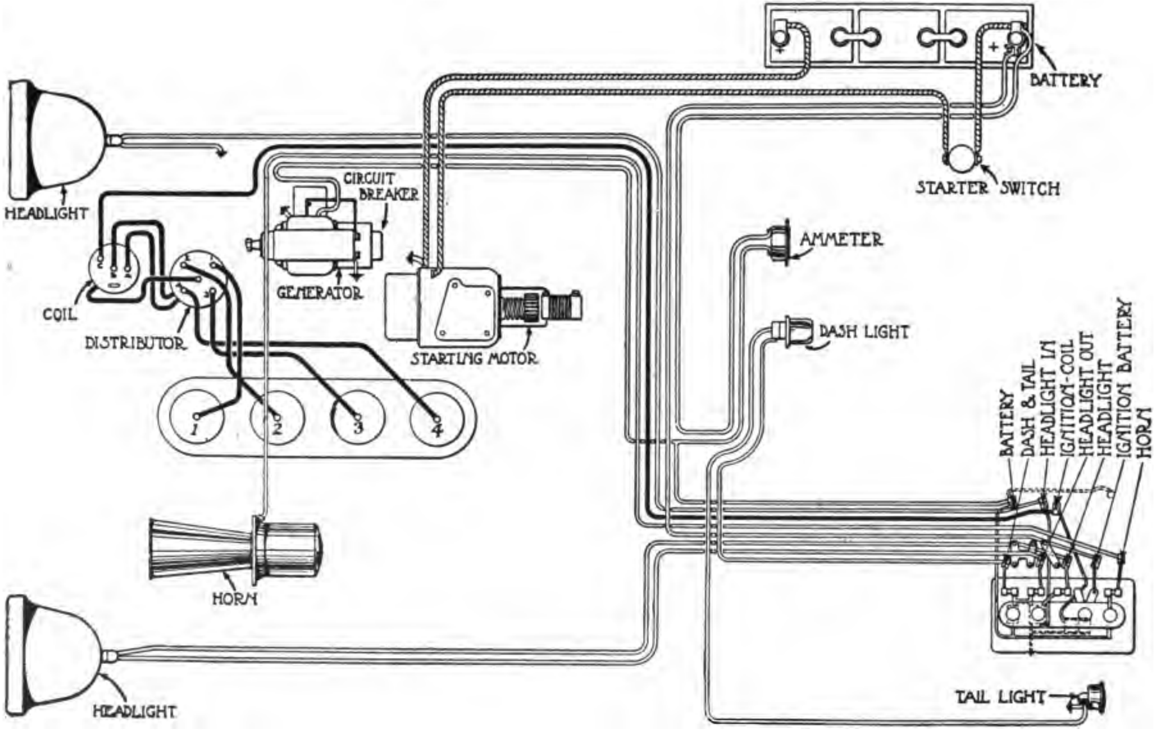
Generator Tests. The following tests will be found an aid in locating failure of the generator.

Field. To test the field coils, lift the brushes off the commutator and insert a piece of fiber or clean dry wood. Close the battery cut-out by pressing the finger on the contacts. The ammeter should then register about one ampere if the coils are all right.

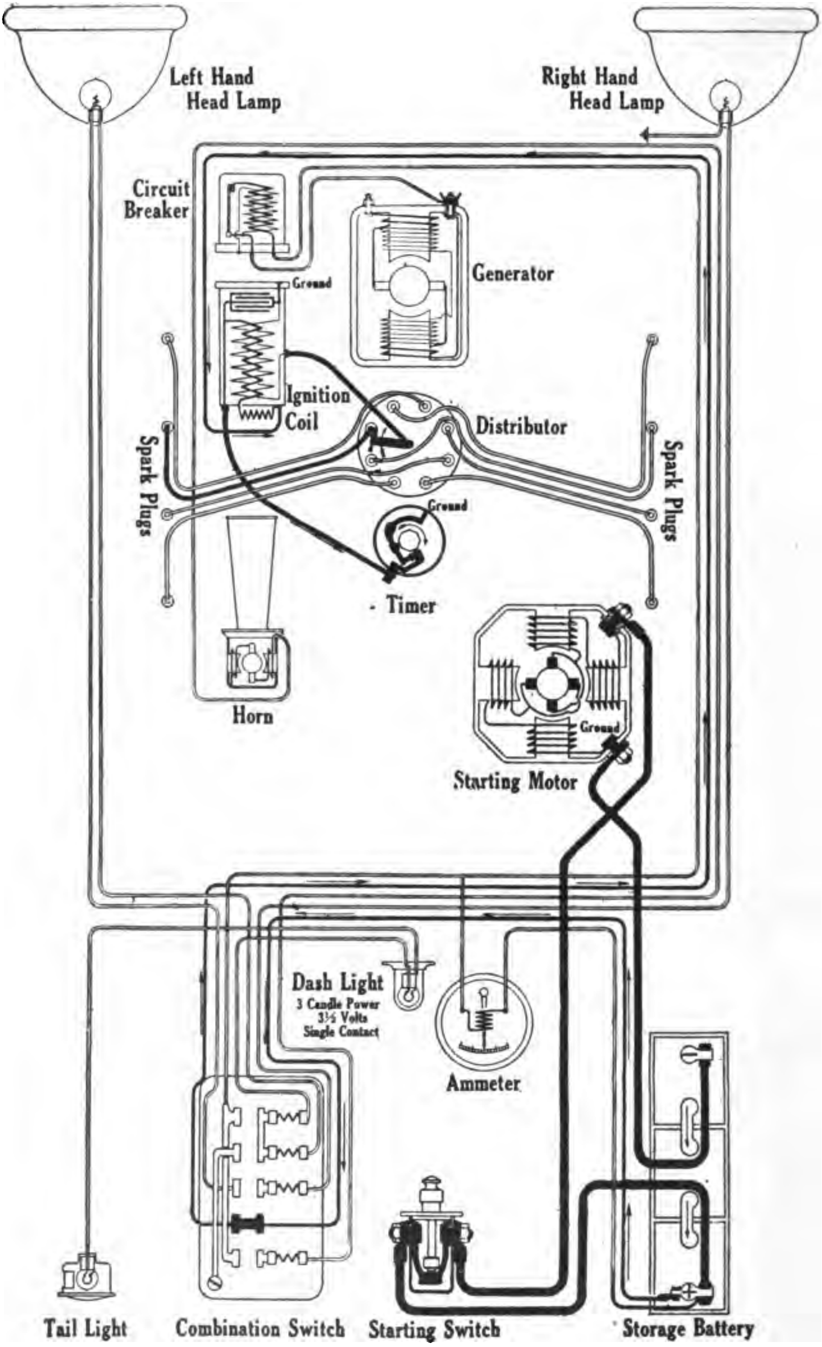
Armature. To test the armature, remove the driving chain and close the cut-out as before. This will *motorize* the generator and it should then run at 650 to 750 r.p.m., drawing 3 to 3½ amperes, if its windings are in good condition. This refers to the generator on Overland Model 80 and Model 81. The Model 82 generator should run at 275 r.p.m. on a current of 2 to 2½ amperes.

Grounds. Tests for grounded windings in either the field or armature coils can be carried out with the aid of the testing-lamp outfit described. Remove the brushes, place one test point on a commutator segment and the other point on the armature shaft; if the coil is all right the lamp will not light. To test the field coils, first break all intentional ground connections (these can be noted by consulting the diagrams); then place one point of the testing set on the machine frame and the other point on a terminal of the field coil. If the lamp lights up, there is a ground which must be removed.

In case any faults are located in the windings it will usually be found advisable to consult the manufacturer's service station



Auto-Lite Starting and Lighting System on Willys-Knight, Model 88-4
Courtesy of The Willys-Overland Company, Toledo, Ohio



Auto-Lite Starting and Lighting System on Willys-Knight, Model 88-8
Courtesy of The Willys-Overland Company, Toledo, Ohio

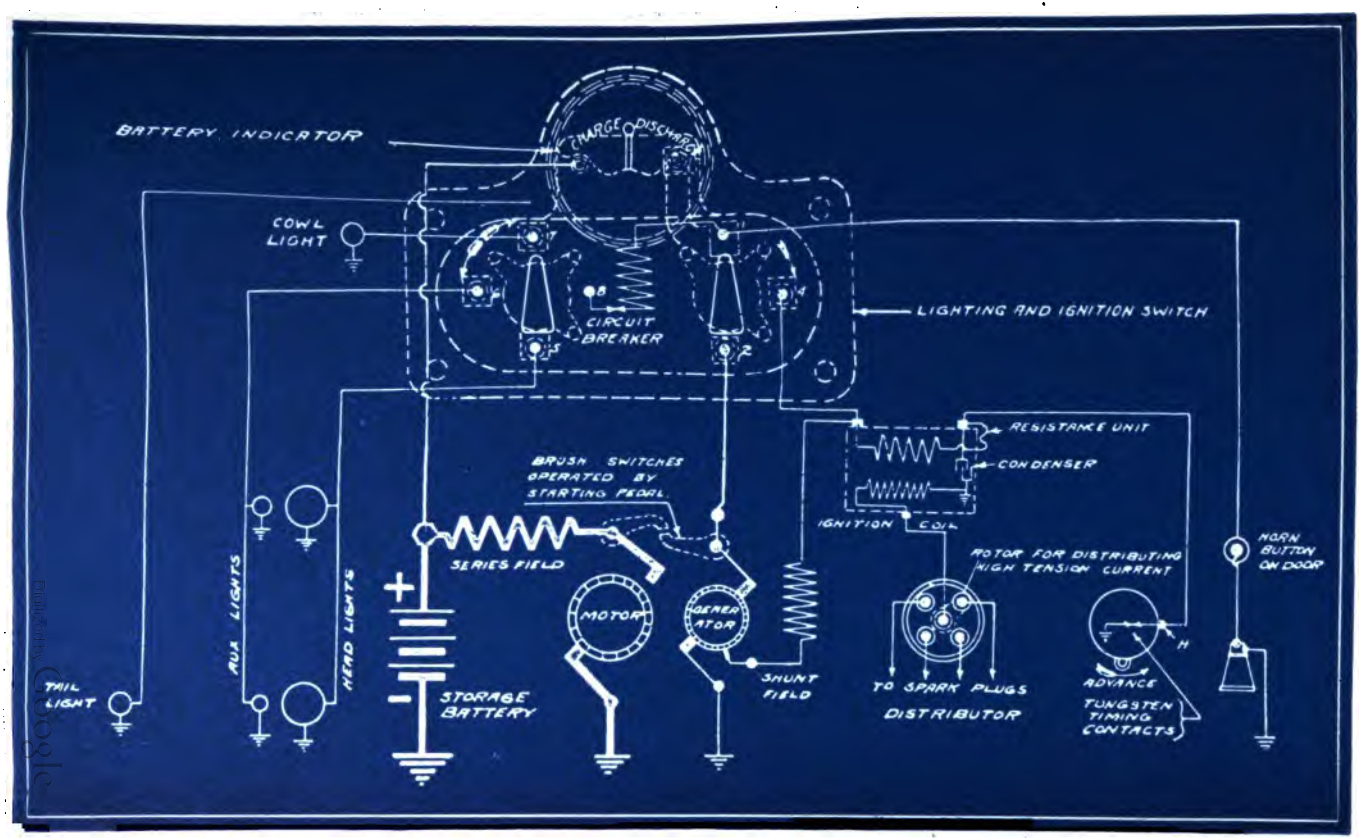


PLATE 9—DELCO STARTING AND LIGHTING WIRING DIAGRAM FOR BUICK CARS, MODELS E-34-35 AND E-4 TRUCK

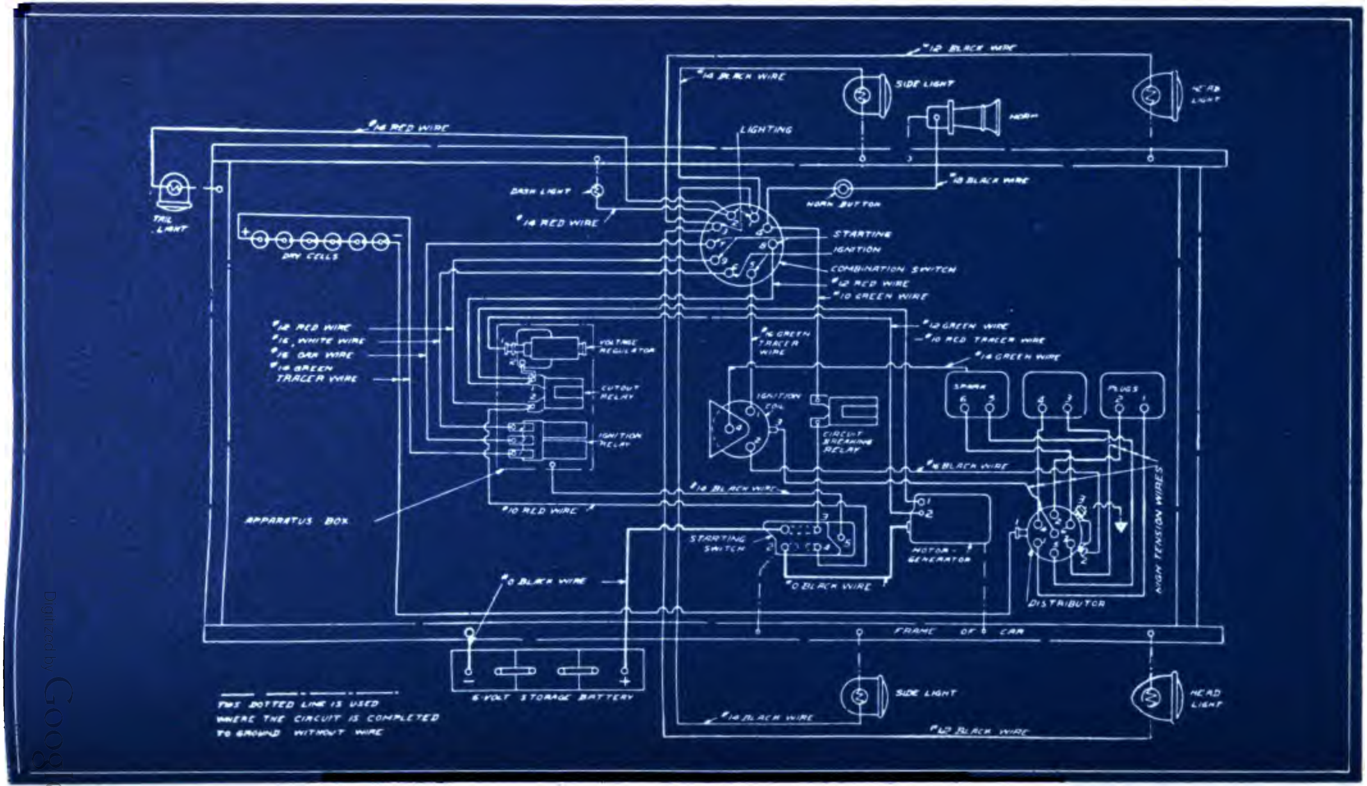


PLATE 10—DELCO WIRING DIAGRAM FOR BUICK 1914 CARS, MODEL B-54-55

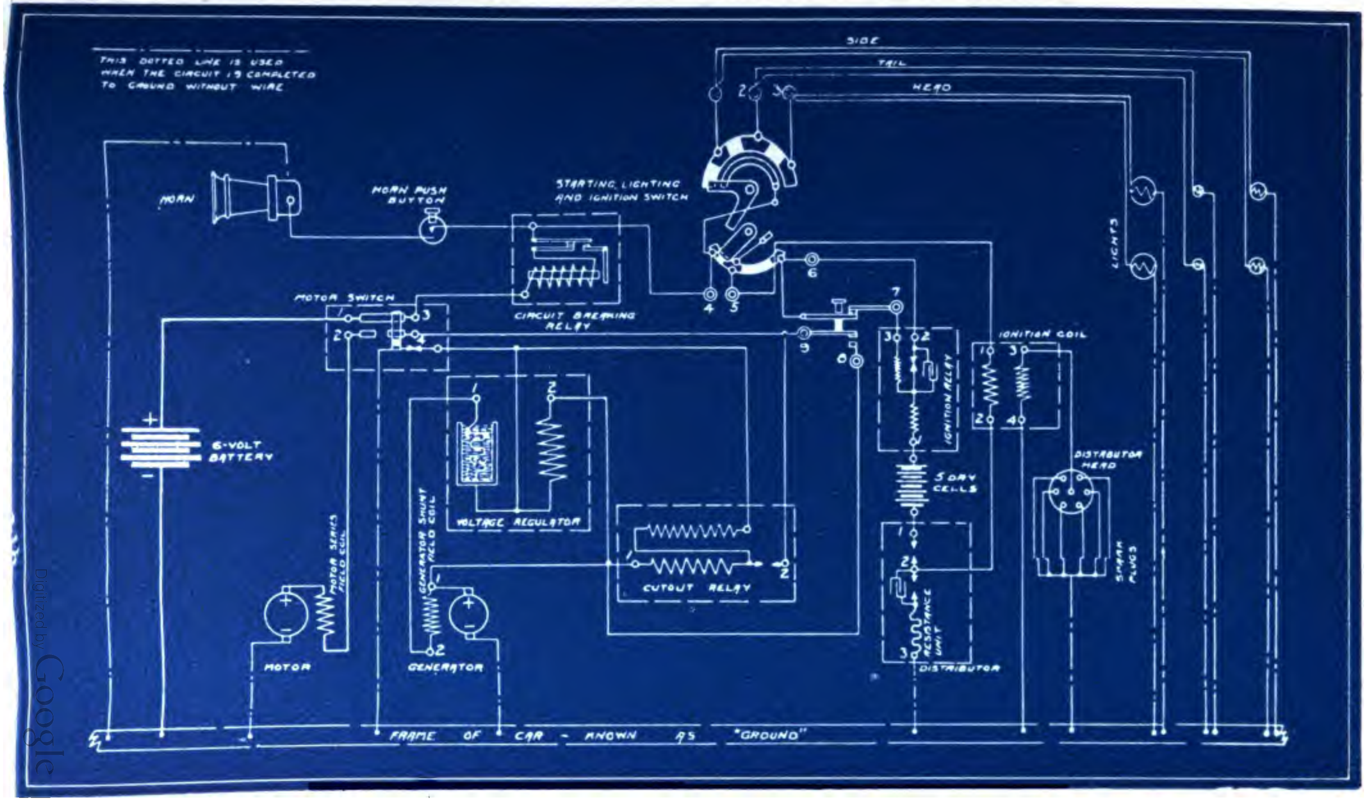


PLATE 11—DELCO CIRCUIT DIAGRAM FOR BUICK 1914 CARS, MODEL B-54-55

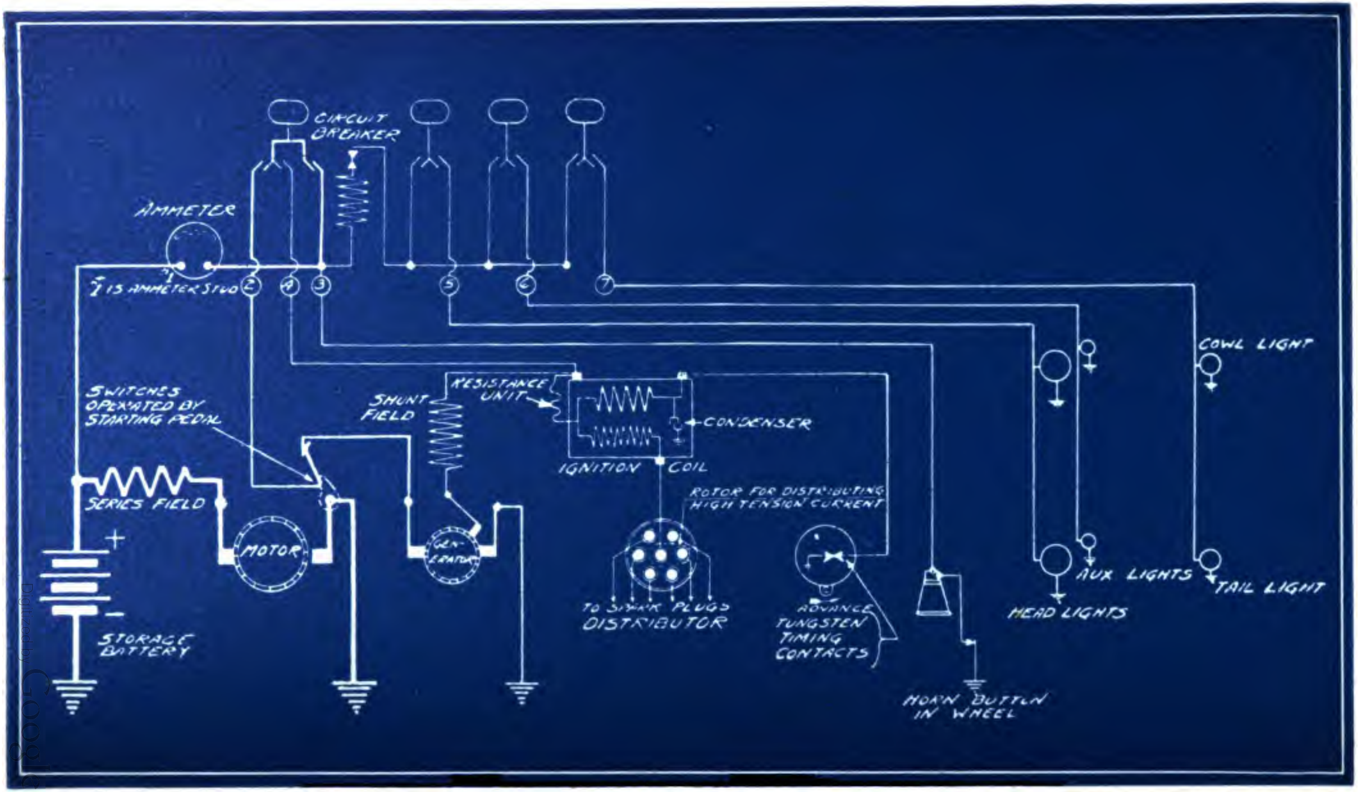


PLATE 12—DELCO WIRING DIAGRAM FOR BUICK 1916 CARS, MODEL D-54-55

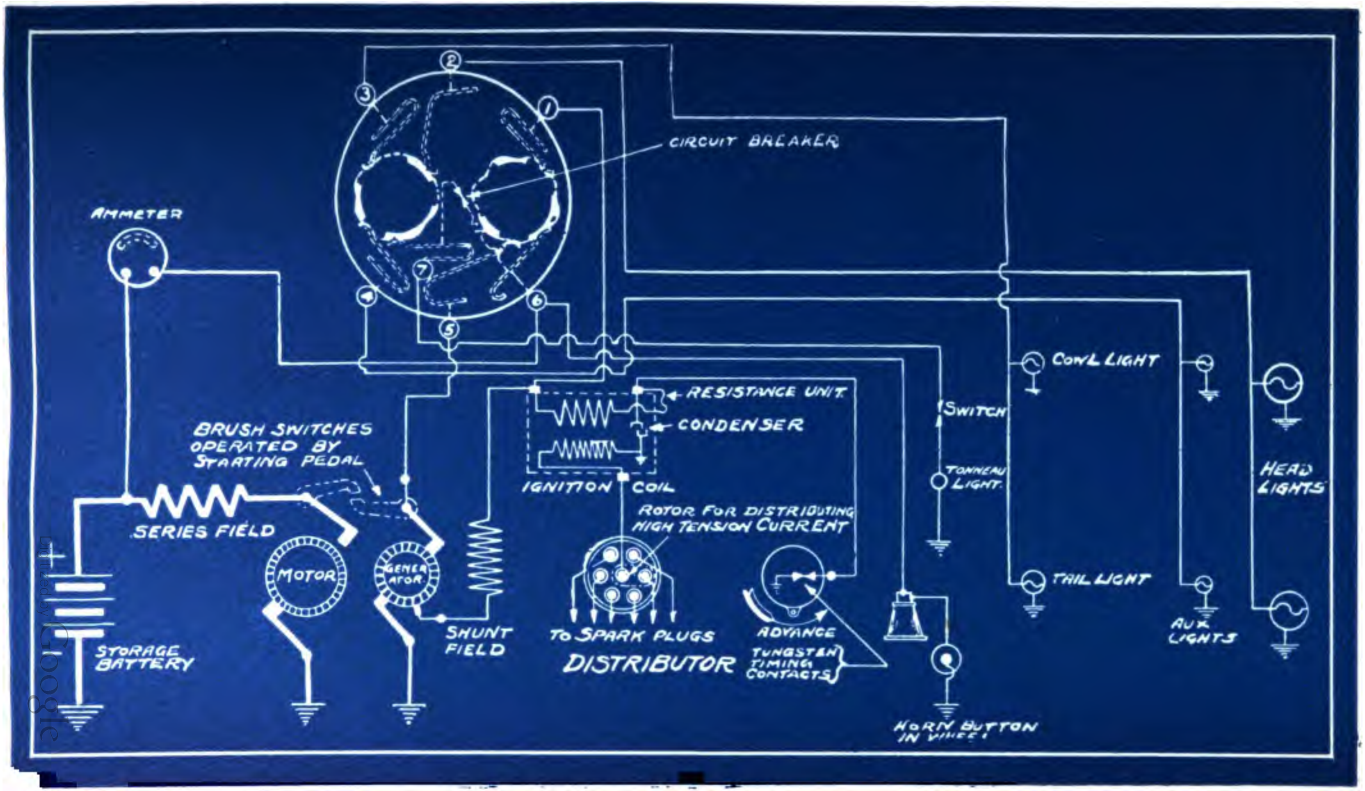


PLATE 18—CIRCUIT DIAGRAM FOR BUICK FOUR- AND SIX-CYLINDER 1919 CARS, MODELS 44-50, DELCO SYSTEM

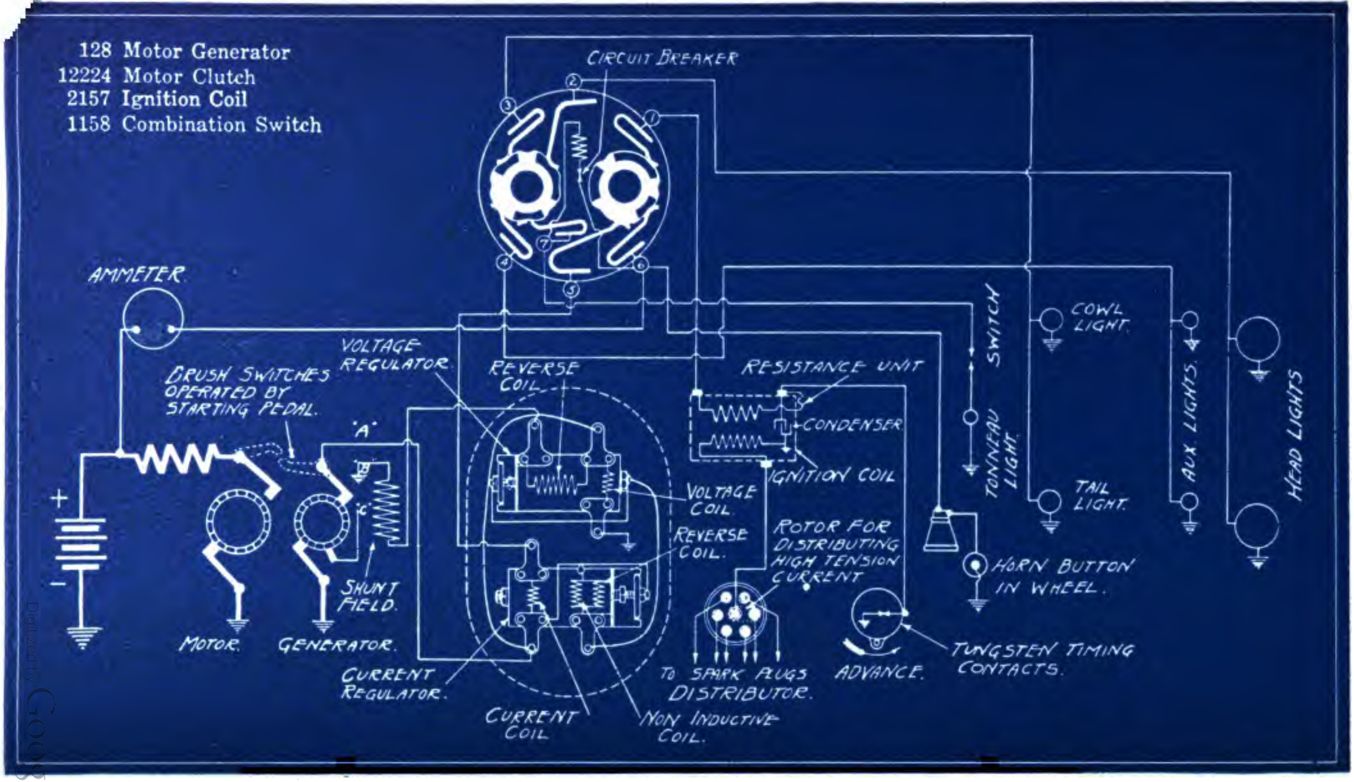


PLATE 13A—DELCO WIRING DIAGRAM FOR BUICK EXPORT 1920, MODELS KX-44, 45, 49

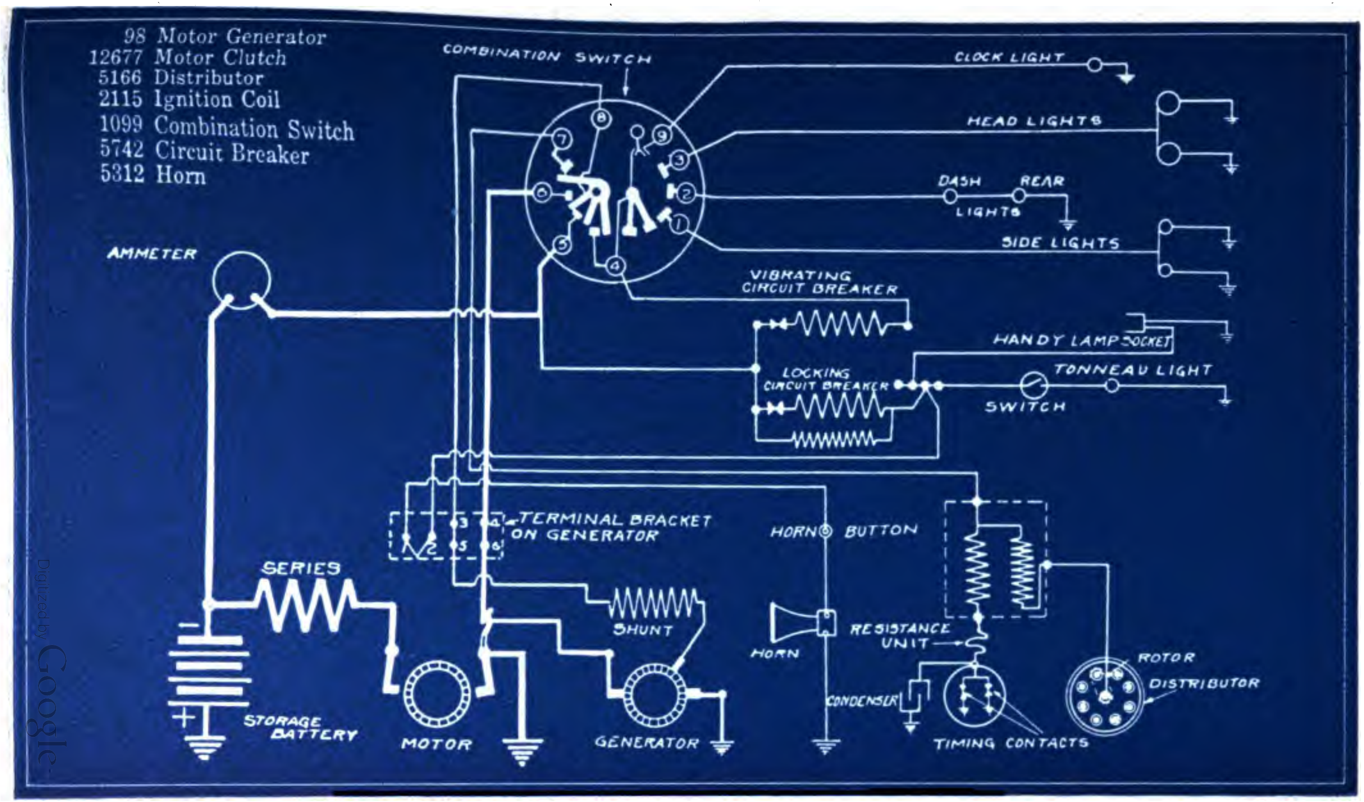


PLATE 13B—DELCO WIRING DIAGRAM FOR 1919 CADILLAC, MODEL 57

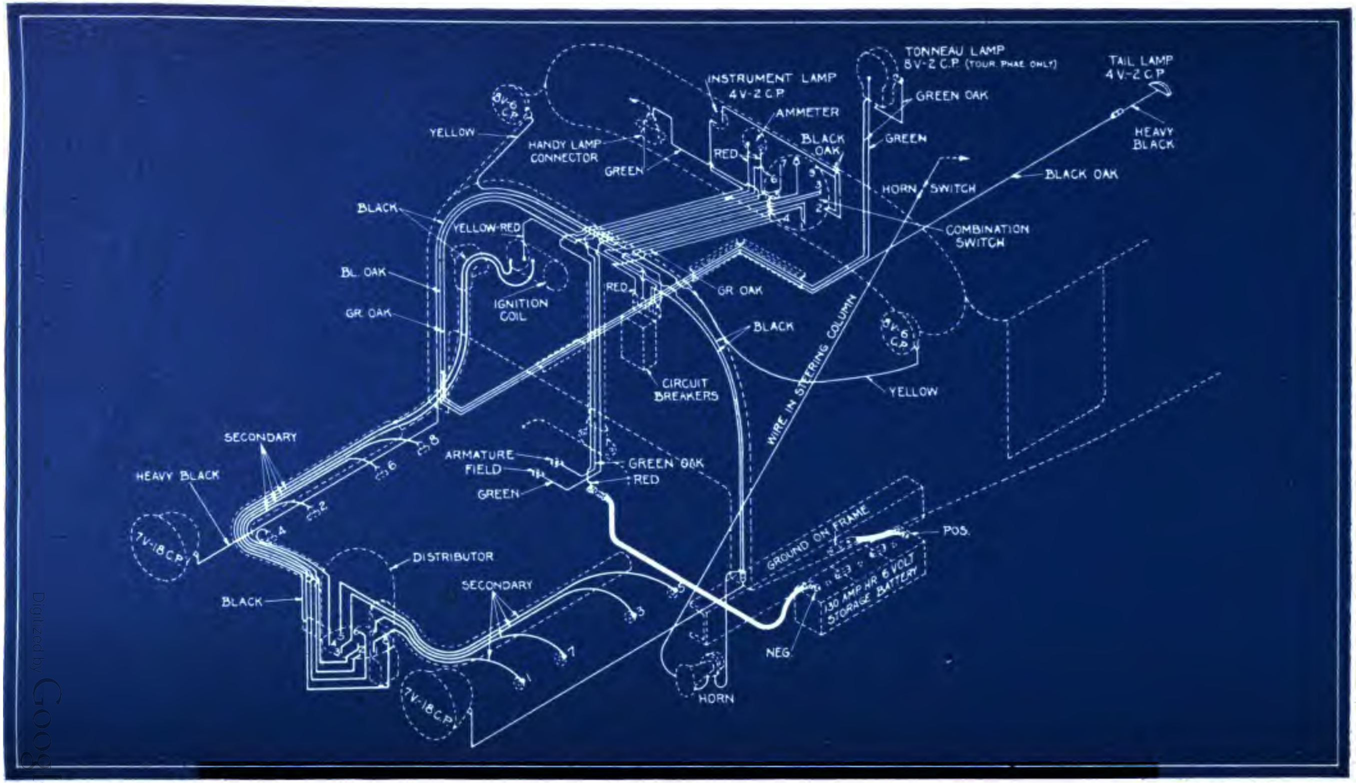


PLATE 19C—PICTORIAL WIRING DIAGRAM FOR ALL CADILLAC OPEN CARS, 1920 DELCO SYSTEM

or the factory direct, as either armature or field winding is something that is beyond even the best equipped of garages.

Battery Cut-Out Tests. Failure of the battery cut-out to operate will most frequently result from pitted or blackened contact points. Clean and true up with fine sandpaper which should be drawn back and forth between them while slight pressure is applied to the upper one, taking care to keep the sandpaper at right angles to the vertical plane of the points, as otherwise they will be put out of true. See that the faces of both points come together over their entire surface when pressed together with the finger.

Operation. Test for operation by sending the current from five dry cells in series through the coil of the cut-out. The points should come together with a snap as soon as the circuit is completed and should hold fast as long as the current is on. This test should not be continued too long, however, as the dry cells will weaken. In case the armature is not attracted, leaving the points in the open position when the battery current is sent through it, inspect the connections from the binding posts to the coil. The wire is small and may have broken from vibration.

Should no circuit be found through the coil with the dry battery, try the test-lamp outfit on the 110-volt circuit, holding one point down on a binding post and just touching the other momentarily with the second point. If the lamp fails to light, there is a break in the coil and the cut-out should be returned to the manufacturer.

BIJUR SYSTEM

6-Volt; Two-Unit; Single- or Double-Wire, According to Make of Car. Also 12-Volt; Single-Unit

Generator. The generator is a special reversible type. Due to the reversible characteristics of the machine it may be connected in either direction and it will assume the proper polarity for charging the storage battery.

Regulation. This is the constant-voltage type, the regulator and battery cut-out being mounted directly on the generator. The principle of this method of regulation is to maintain the voltage of the generator constant, the current output depending on the resistance of the circuit and varying with the state of charge of the battery. This is accomplished by the use of a magnetic vibrator similar in principle to the ordinary electric bell, or buzzer, though it takes a different form, Fig. 226. *H* is the magnet winding, *A* the soft-iron core of the magnet, and *G* the vibrating armature. To prevent *G* from coming directly in contact with the pole piece on the upper end of *A*, a stop pin *I* is provided. *C* and *F* are the contacts, *C* being held against *F* by the tension spring *E* and is pulled away from *F* by the magnetic pull of coil *H* in armature *G*. These contacts are mounted on vibrating reeds (thin strips of spring brass) placed at right angles to each other. Contact *C* and its reed are attached to the armature *G*, and stop pins *B* limit the lateral movement of this contact. *F* and its reed are also mounted on an arm as shown.

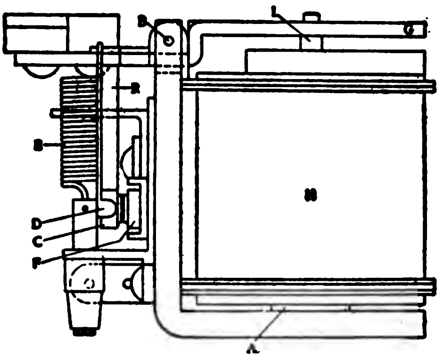
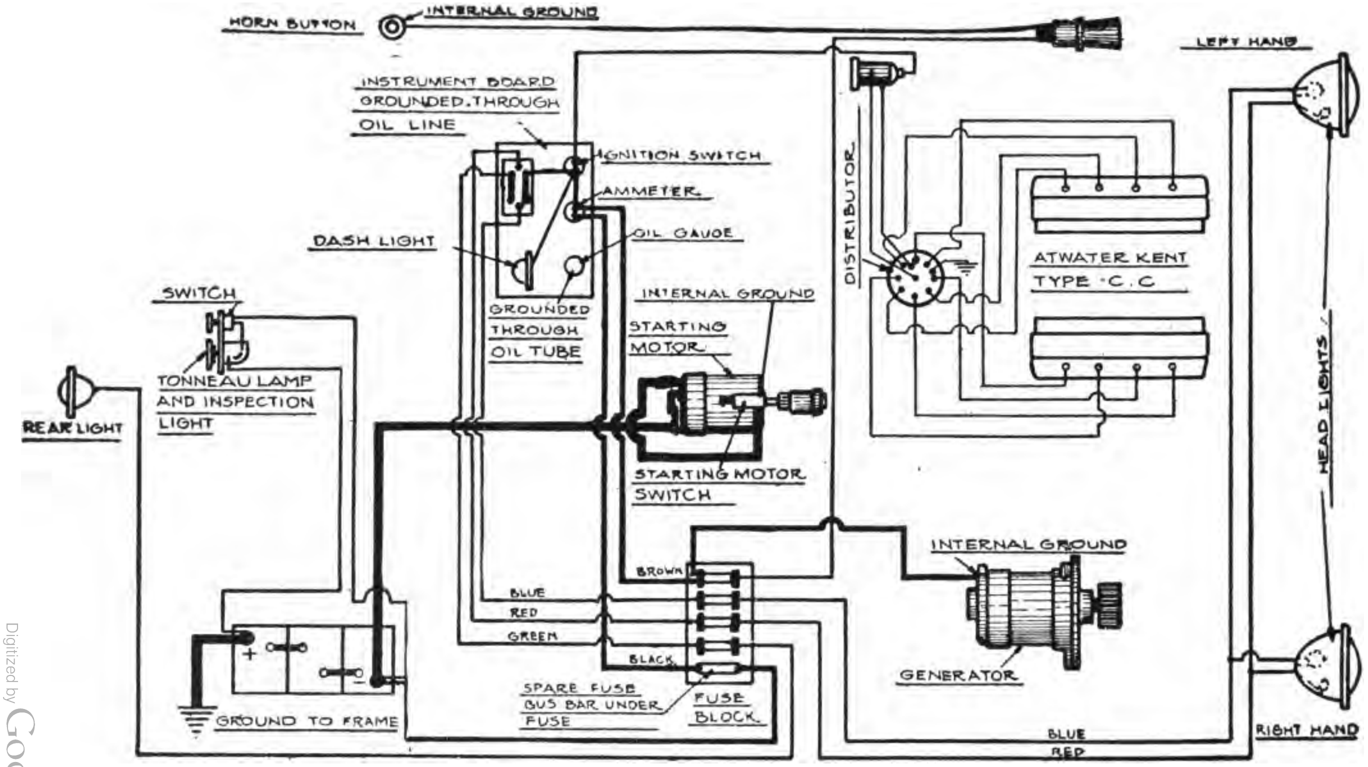
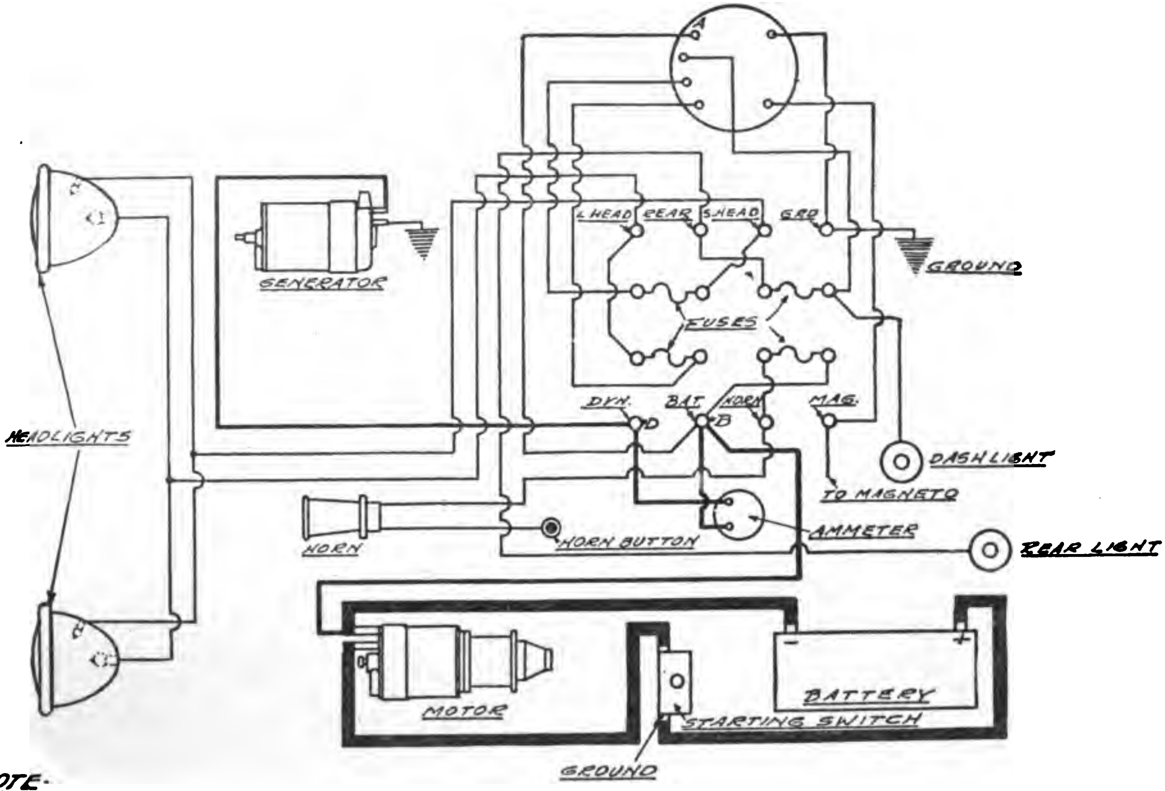


Fig. 226. Bijur Vibrator Voltage Regulator
Courtesy of "The Horseless Age"

When a current flows through the magnet coil the armature *G* is attracted, automatically released by the breaking of the circuit, and again attracted so that it vibrates, the rate of vibration depending upon the amount of current. As the vibrator is included in the field circuit the current in the latter is accordingly pulsating, and as a field circuit, owing to its heavy iron core has considerable self-induction, the amount of current flowing through it will decrease in proportion to the rapidity of the vibration or pulsations. To prevent the field losing its excitation altogether every time the vibrator opens the circuit, the latter is not connected directly in circuit with the shunt winding of the generator, but is placed across the terminals of a resistance unit in series with the shunt field. This also prevents the arcing or heavy sparking that otherwise would result from the breaking of a circuit having so much inductance. Failure of a vibrating regulator is usually caused by the contact points sticking or fusing together owing to the heat. Mounting the points on reeds is designed to prevent this as the vibration due to the operation of the car keeps them moving laterally, thus overcoming the formation of a cone of metal on the negative contact point caused by the small particles transferred from the positive.



Bijur Starting and Lighting Installation on King Eight-Cylinder Cars, Model EE
Courtesy of Bijur Motor Lighting Company, Hoboken, New Jersey



NOTE.
CARS FROM 1 TO 500 INCLUSIVE,
CONNECTION IS MADE FROM "A" TO "D"
INSTEAD OF "A" TO "B".

Bijur Starting and Lighting Installation on Jordan Sixty
Courtesy of Jordan Motor Car Company, Cleveland, Ohio

Figure 13

Starting Motor. This is of the series-wound multipolar type. The installation of motor and starting switch as mounted on Hupp cars is shown in Fig. 227.

Instruments. A dash ammeter is supplied. With constant voltage control the amount of current delivered to the battery by the generator depends upon the condition of the former. With battery almost discharged, its voltage is lowered and the current reading may then be as high as 15 to 20 amperes. With battery fully charged and no lights on, the reading will decrease to 5 amperes or less, the charging current at all times depending upon the state of charge of the battery.

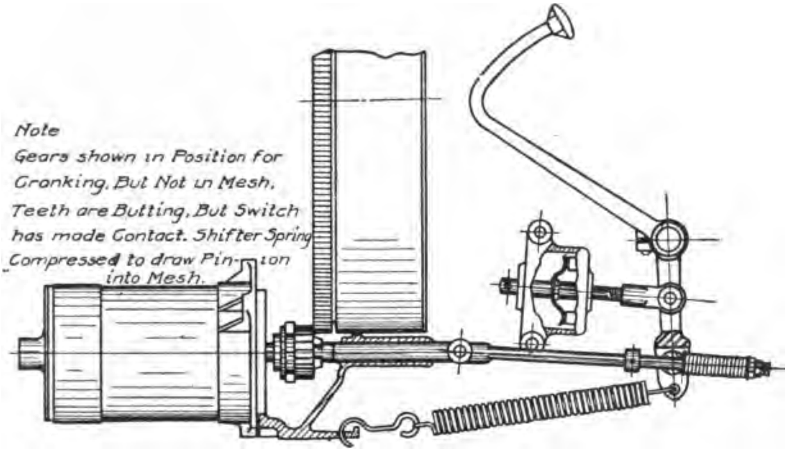

Note
Gears shown in Position for Cranking, But Not in Mesh. Teeth are Butting, But Switch has made Contact. Shifter Spring Compressed to draw Pinion into Mesh.

Fig. 227. Bijur Starting Motor as Installed on the Hupp

Wiring Diagrams. *Winton.* This, as shown in Fig. 228, is a single-wire system. The generator is located alongside the transmission case and is belt-driven, provision for belt adjustment being made by swinging generator to tighten belt. The numbers on the wires indicate the sizes of wire used for connecting the various apparatus. Ground connections are on engine and transmission case. In this installation the starting switch is mounted directly on the starting motor. A spare lamp circuit is provided on which a portable, trouble-hunting lamp may be connected. Fuses are provided on all lamp circuits.

Jeffery. Fig. 229 illustrates the six-volt two-wire system used on the Chesterfield Six Model. With the exception of the out-of-

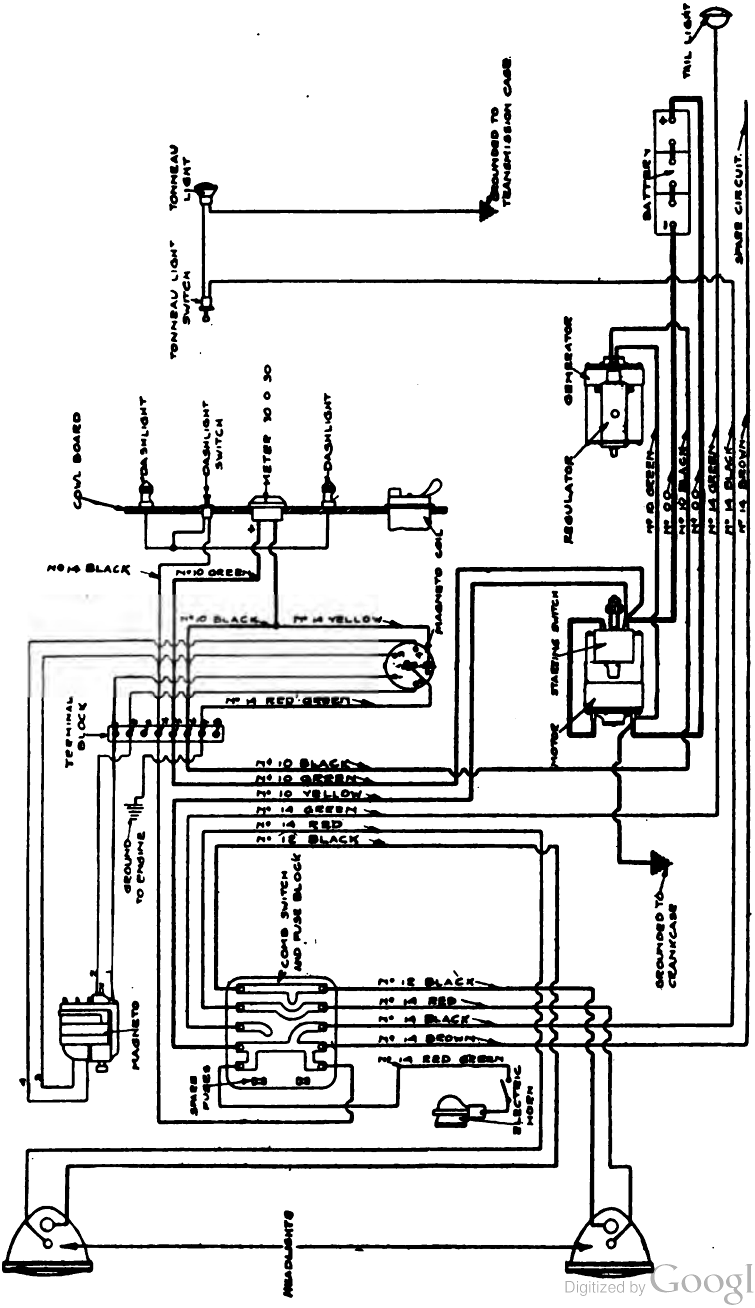


Fig. 228. Bijur System as Installed on the Winton

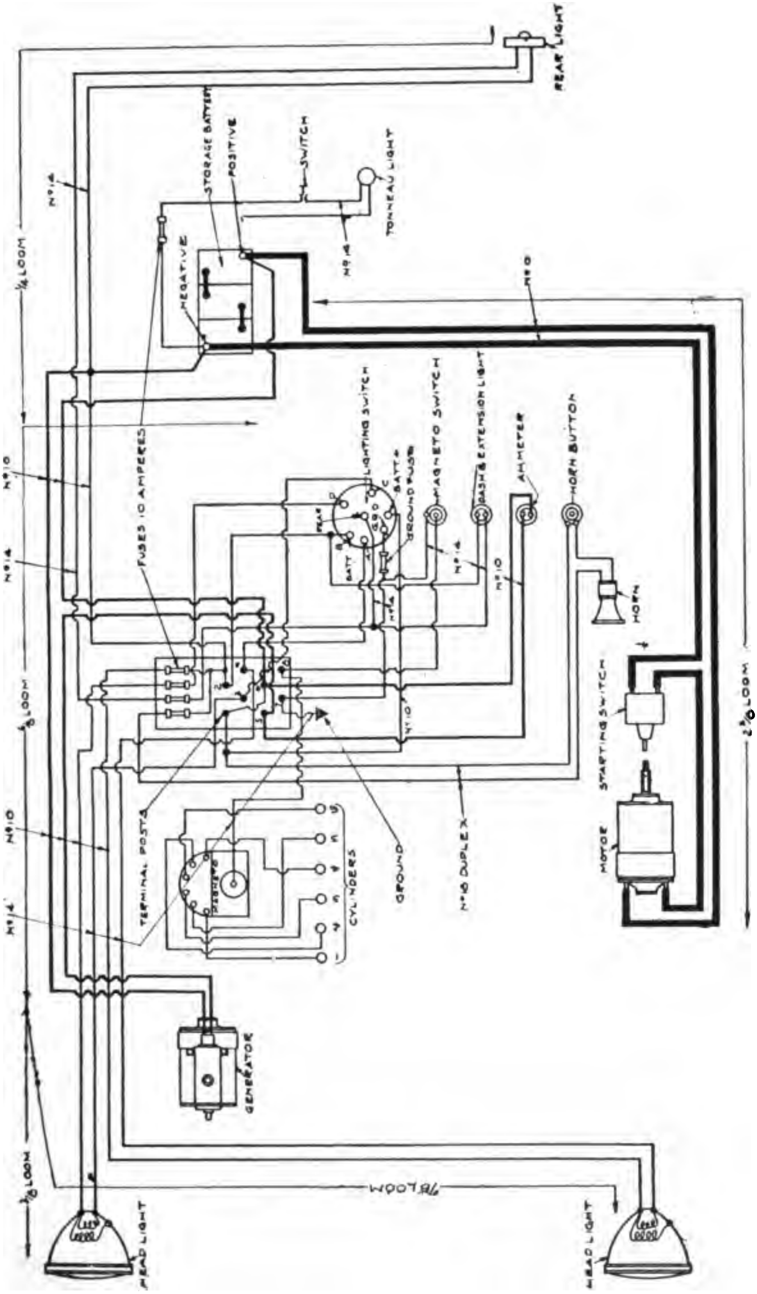


Fig. 229. Bijur System (Two-Wire) Installed on the Jeffery Chesterfield Six

focus lamps in the headlights for city running which are on the three-wire plan, one side being grounded, all apparatus is connected with two wires. In addition to lamp fuses, the ground connection is also fused. The blowing of any of these fuses does not affect the ignition circuits. The generator is mounted on the right side of the motor and is driven through a flexible coupling from the timing-gear shaft. At its rear end, the generator is connected through a jaw coupling to the water pump, this shaft also serving to drive the magneto. The starting switch is mounted on a housing covering the motor pinion, the starting motor being mounted on the left side of the engine. A five-way switch provides lamp control.

Hupp. Fig. 230 shows the 6-volt single-wire system. This diagram is simplified by the omission of the magneto, current from the battery being supplied to a single coil and distributor system for this purpose. The generator is bolted to an extension on the right side forward of the engine and is driven by silent chain from the crankshaft. The generator is of the third-brush regulation type. The field windings are protected by a 12-ampere fuse. There is a four-way switch for lighting circuits.

Apperson. The 6-volt two-wire system is shown in Fig. 231. The generator is of the third-brush regulation type. A "charge indicator" is fitted instead of an ammeter, having three readings—*charge*, *floating*, and *discharge*. *Floating* is the neutral position and the indicator should show this when the engine is stopped and no lights are on, and may show either *charge* or *floating* at car speeds in excess of 12 miles per hour with lights on, according to the condition of the battery. Generator fields are protected by a 12-ampere fuse.

Scripps-Booth. In this connection is used the 12-volt single-wire system employing a single unit or dynamotor for charging and starting. The dynamotor is driven by silent chain from the crankshaft. At speeds above 10 miles per hour, it acts as a generator to charge the battery; at speeds below this point, it automatically acts as a motor to drive the engine. Control is by three-way switch, having *on*, *off*, and *idle* positions.* In the *on* position, the dynamotor is connected to the battery, the generator field circuit is closed, and the ignition circuit is closed. This is the normal operating position. In the *off* position, all circuits are opened and the car cannot be run. Shifting the switch to the

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* Earlier models like Fig. 232 used a two-way switch.

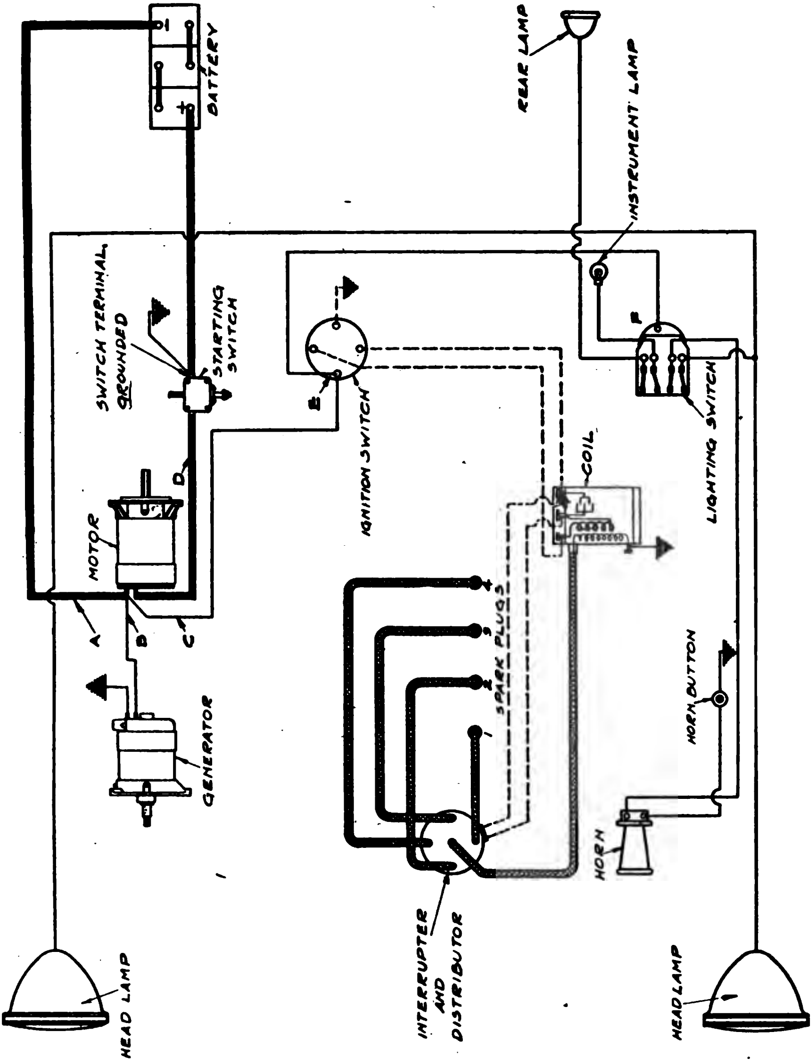


Fig. 230. Wiring Diagram for the Bijur System on the Hupmobile

idle position closes the ignition circuit so that the engine can be operated, but the dynamotor is disconnected from the battery and its field circuit is opened so that it generates no current.

Fig. 232 shows the wiring diagram as used on the earlier models of the Scripps-Booth, while Fig. 233 is the diagram of later models

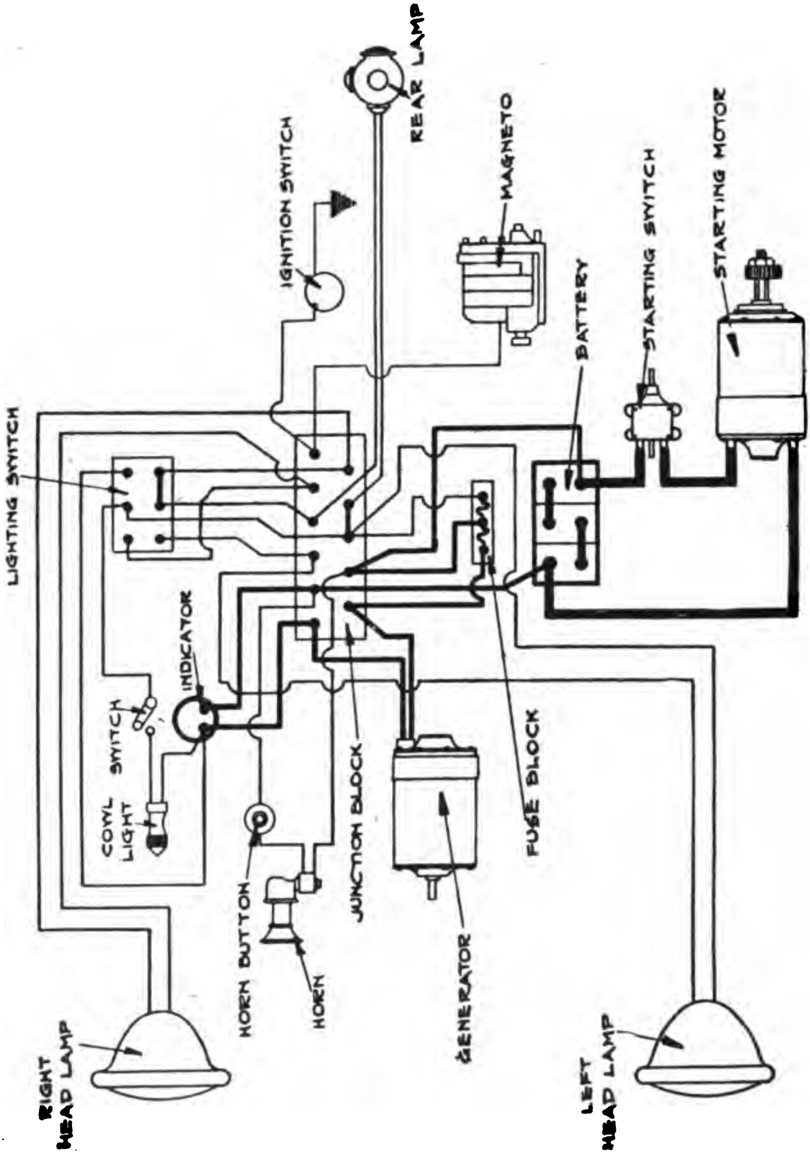


Fig. 231. Wiring Diagram for the Bijur System on the Apperson Car

of the same make. A current indicator shows the operation of the system and a four-way lighting switch is employed. The generator produces current at 12 volts and charges the storage battery cells in series. Fourteen-volt tungsten lamps are used.

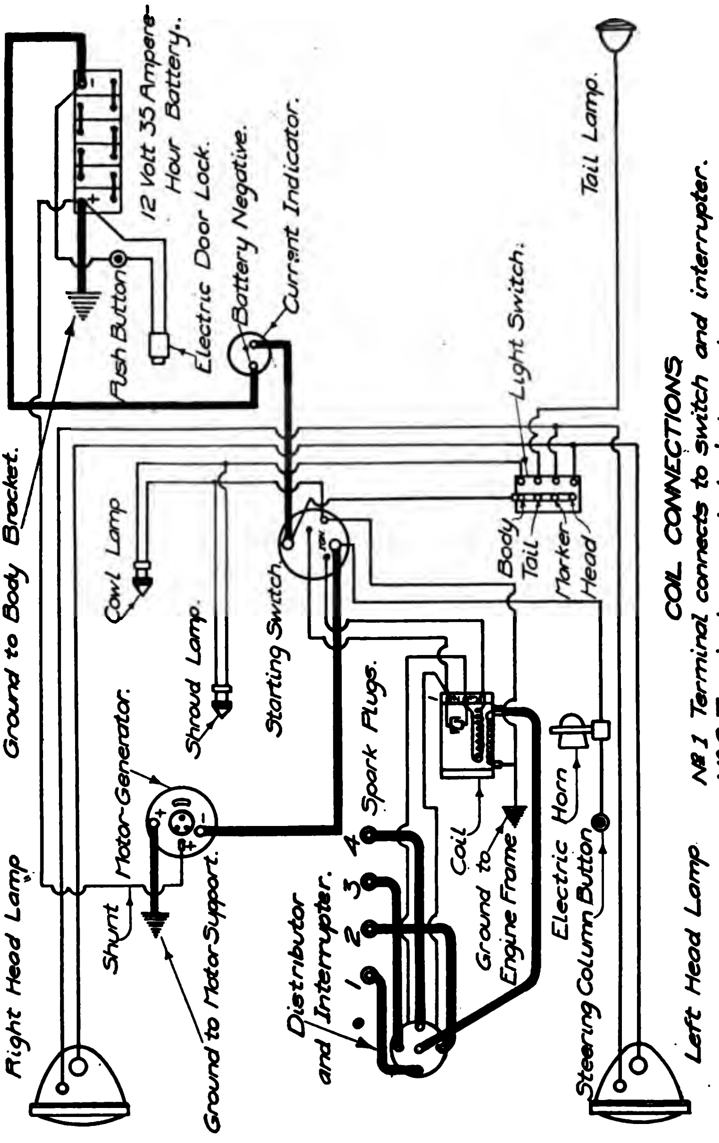
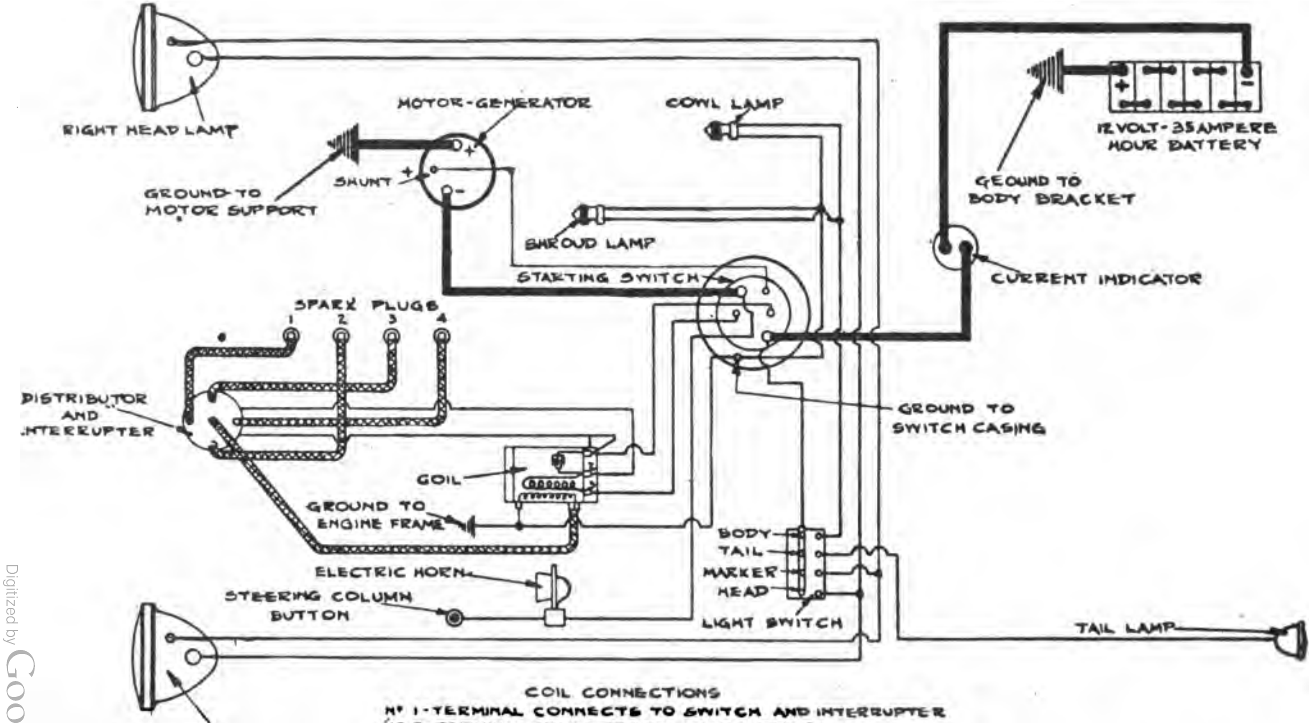


Fig. 232. Bijur System as Installed on Earlier Models of Scripps-Booth Cars

Instructions. *Winton.* No *charge* reading will be indicated on the ammeter when the engine is running (on high gear or direct



COIL CONNECTIONS
Nº 1-TERMINAL CONNECTS TO SWITCH AND INTERRUPTER
Nº 2-TERMINAL CONNECTS TO INTERRUPTER
No 3-TERMINAL CONNECTS TO SWITCH

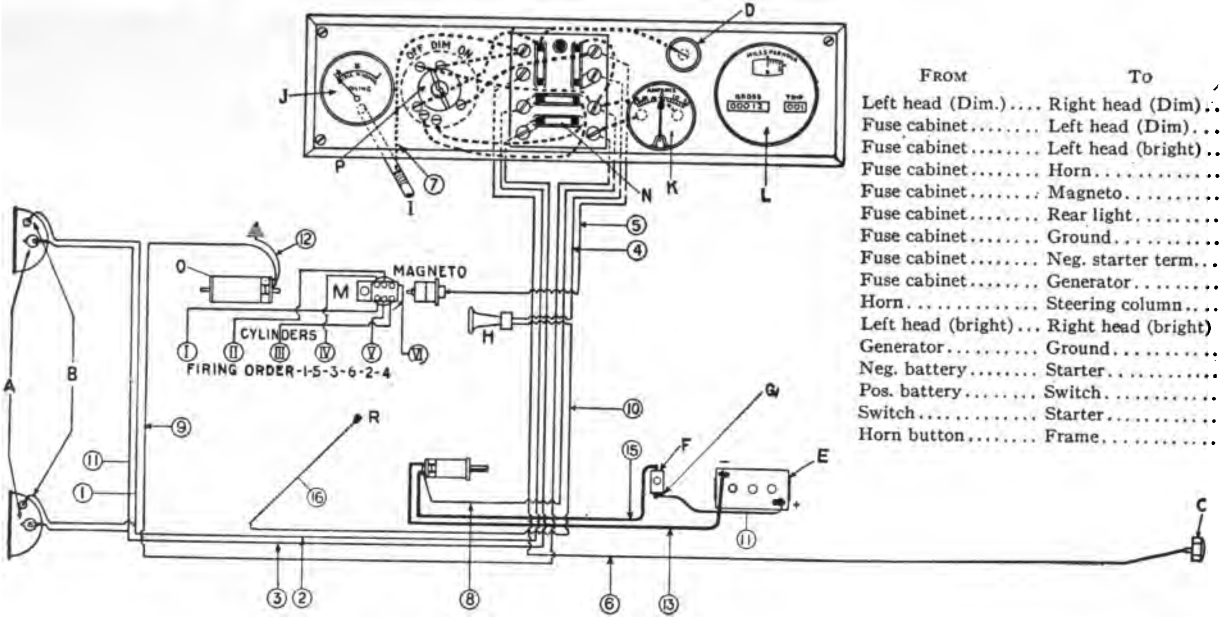
Fig. 233. Bijur System as Installed on Later Models of Scripps-Booth Cars

drive) at a car speed of less than 10 miles per hour. Failure to indicate a charge at speeds higher than this is a sign that the generator belt is too loose or that the generator itself is inoperative. To determine this, remove No. 10 black wire, Fig. 232, connected to No. 6 post on the terminal block, which goes into the aluminum box above it. Connect a voltmeter between this wire and the chassis and run the engine at a speed corresponding to a travel of 15 miles per hour on high gear. The voltmeter should indicate 7.3 to 7.4 volts. Instructions regarding brushes, commutator, and tests of armature- and field-winding circuits with the aid of testing lamp as given in connection with the Auto-Lite system apply to determine the nature of the fault in the generator. A special disconnecting plug is incorporated in the regulator box on top of the generator. This plug has two flat parallel faces and should never rest in its receptacle so that these flat faces stand in a vertical position, but should be pushed in and turned in either direction past its central position until it locks. When making tests for generator faults see that this plug is in the proper position to close the generator circuit.

To remove the regulator box from the generator, the disconnecting plug should be pushed in and turned to its central position when the plug may be withdrawn from its socket. After removing the plug, the knurled screw on top of the regulator box should be loosened and the box lifted by grasping it and the plug receptacle at the same time. Do not hammer the receptacle in order to release the box. If the disconnecting plug is round and knurled on the portion extending from the receptacle, the plug may be withdrawn when the V-groove extending horizontally on the plug matches with the slot at the top of the receptacle. The plug should never be left in this position, but should be turned in either direction until it springs forward and locks. Every five hundred miles, this disconnecting plug should be pushed inwardly to unlock it, and turned past its vertical position until it springs forward and locks. In carrying out any repairs or tests involving the disconnection of any of the wires which might cause a short circuit by coming in contact with metal parts of the car, the cable connected to the positive terminal of the battery should be disconnected and its bare end taped. This naturally applies to all grounded electrical systems and not merely to the car under consideration.

Jeffery (*Chesterfield Six*). Instructions for failure of generator, starting motor, lamp circuits, etc., are the same as those given in connection with other installations, except that in making tests the fact that two-wire circuits are employed must be borne in mind and connections made accordingly. The headlights supplied are special double-filament lamps, one of the filaments being out of focus to provide a non-glaring light for city driving. Where emergency replacements are made with standard single-filament lamps (double-contact type), the lamp controller should be turned to the *in focus bright* position when the head lamps are to be used. It is not possible to dim the lights under these conditions. In making a head-lamp double-filament bulb replacement, the lamp controller should be turned to the *out of focus dim* position. The new bulb should then be inserted in its socket. The out-of-focus filament in each headlight should then burn dimly. If they do not, the last bulb inserted in its socket should be removed, reversed, and replaced. When bulbs are correctly inserted, the two out-of-focus filaments will burn dimly when the lamp controller is turned to the *out of focus dim* position. Instructions for the use of the disconnecting plug are the same as for the Winton.

To determine whether generator is inoperative remove wire leading from the ammeter to No. 5 post of the junction and fuse block, Fig. 229, then connect voltmeter to terminals 2 and 5 and run engine as previously directed. A fuse is in the ground circuit between the magneto tap and the lamp controller and this fuse will blow if an accidental ground is made on either side of the system. The blowing of this fuse when the lamp controller is in the *off* position, shows that the accidental ground causing it is on the positive side of the system. Should the ground fuse blow when the lamp controller is in the *all bright* or *out of focus bright* positions, it shows that the accidental ground is on the negative side of the system. In testing the wiring to locate grounds, the headlight bulbs should be removed and the ground wire leading to connecting post No. 7 of the fuse and terminal block should be disconnected, and the magneto switch should be placed in the running position. With the ground fuse blown, the following lighting conditions obtain. Controller at *in focus bright* position, lamps will burn normally. At *out of focus bright* position lamps will not light; at *all bright* position

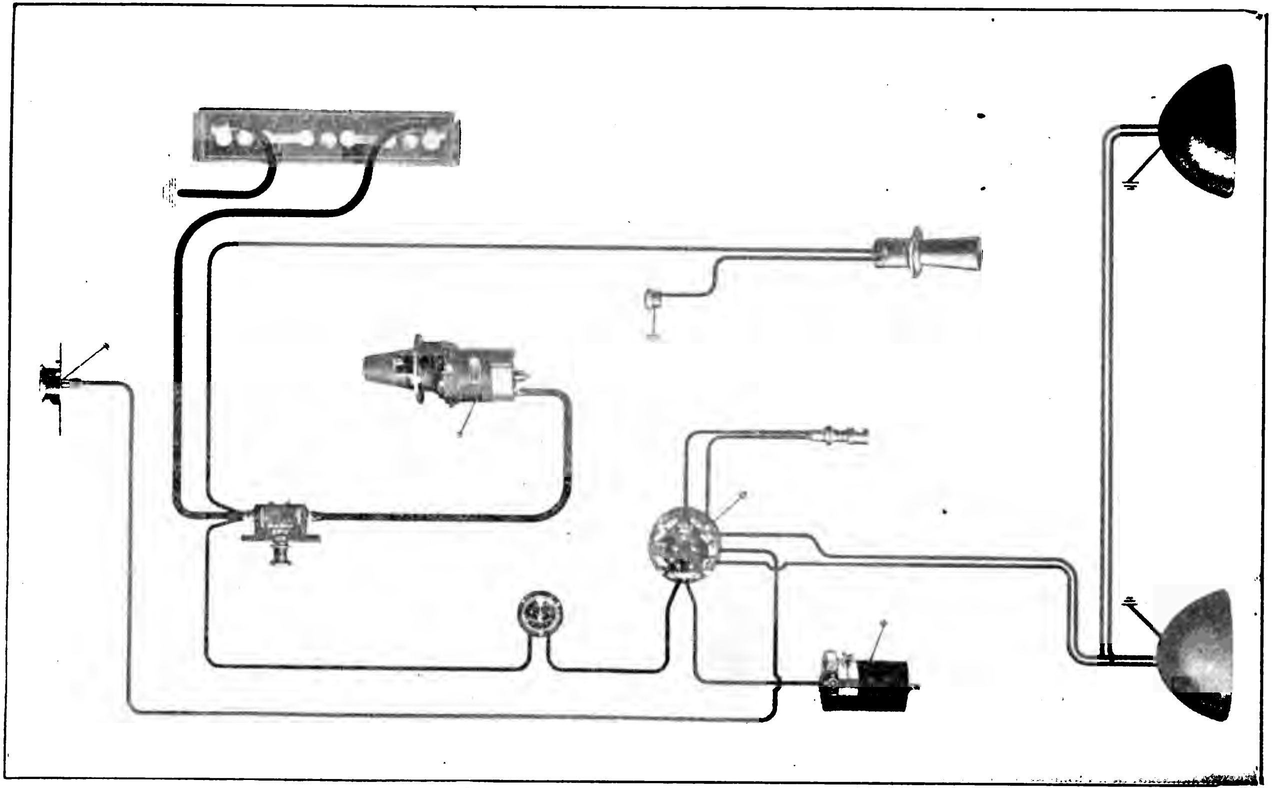


FROM	TO	No.
Left head (Dim.)	Right head (Dim)	1
Fuse cabinet	Left head (Dim)	2
Fuse cabinet	Left head (bright)	3
Fuse cabinet	Horn	4
Fuse cabinet	Magneto	5
Fuse cabinet	Rear light	6
Fuse cabinet	Ground	7
Fuse cabinet	Neg. starter term.	8
Fuse cabinet	Generator	9
Horn	Steering column	10
Left head (bright)	Right head (bright)	11
Generator	Ground	12
Neg. battery	Starter	13
Pos. battery	Switch	14
Switch	Starter	15
Horn button	Frame	16

WIRING DIAGRAM

A—Head light
B—Dimmers
C—Tail light
D—Dash light
E—Battery
F—Starter switch
G—Ground
H—Horn
I—Oil pipe
J—Oil gauge
K—Ammeter
L—Speedometer
M—Magneto
N—Fuse box
O—Generator
P—Switch
R—Horn button

Bijur Starting and Lighting Installation on Jeffery Six, Model 671
Courtesy of Bijur Motor Lighting Company, Hoboken, New Jersey



Wiring Diagram Showing Delco Ignition and Bijur Starting and Lighting Systems for National Highway Twelve
Courtesy of National Car and Vehicle Corporation, Indianapolis, Indiana

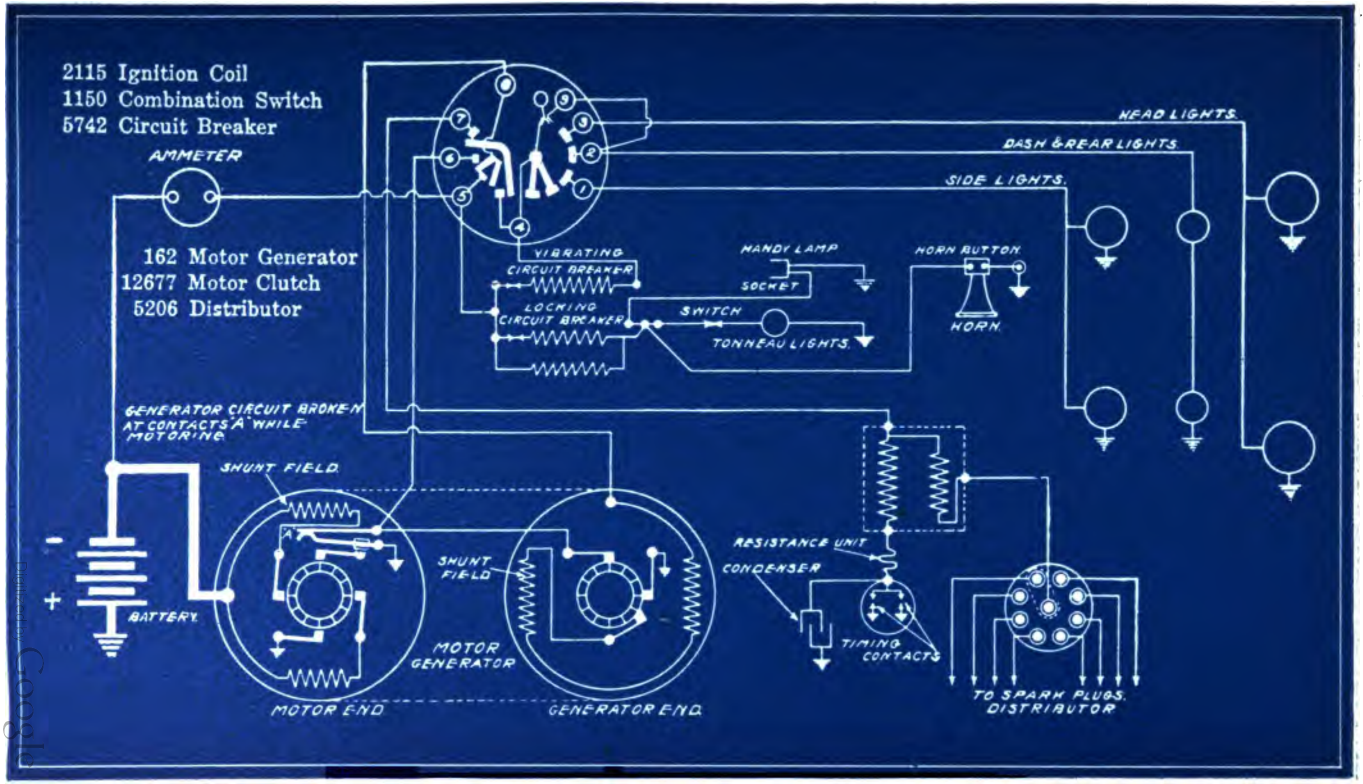


PLATE 13D—DELCO WIRING DIAGRAM FOR 1920 CADILLAC, MODEL 59

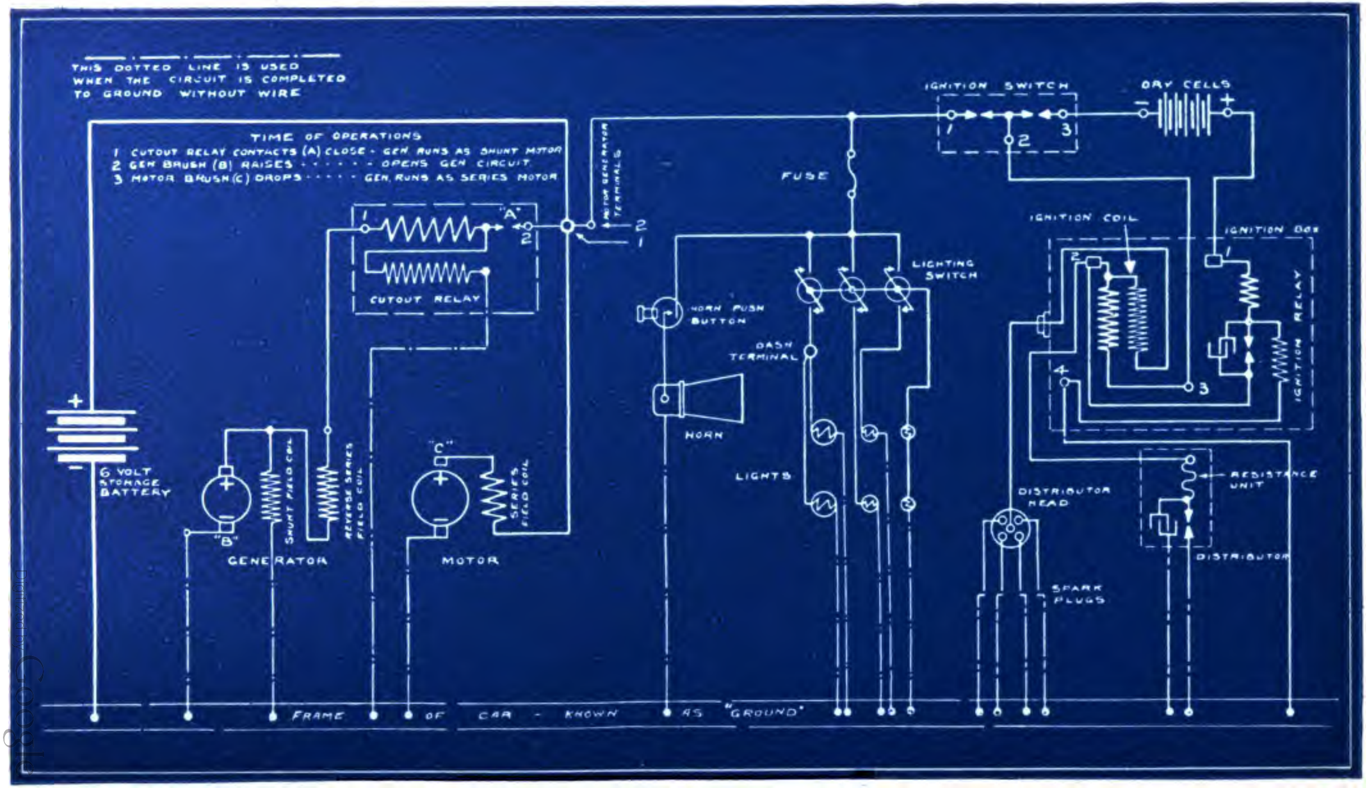

THIS DOTTED LINE IS USED WHEN THE CIRCUIT IS COMPLETED TO GROUND WITHOUT WIRE
TIME OF OPERATIONS
1 CUTOUT RELAY CONTACTS (A) CLOSE - GEN. RUNS AS SHUNT MOTOR
2 GEN BRUSH (B) RAISES - - - - - OPENS GEN CIRCUIT
3 MOTOR BRUSH (C) DROPS - - - - GEN. RUNS AS SERIES MOTOR
6 VOLT STORAGE BATTERY
"B"
GENERATOR
SHUNT FIELD COIL
REVERSE SERIES FIELD COIL
CUTOUT RELAY
"A"
"C"
SERIES FIELD COIL
MOTOR
MOTOR GENERATOR TERMINALS
FUSE
HORN PUSH BUTTON
DASH TERMINAL
HORN
LIGHTS
LIGHTING SWITCH
IGNITION SWITCH
DRY CELLS
IGNITION COIL
IGNITION BOX
IGNITION RELAY
DISTRIBUTOR HEAD
RESISTANCE UNIT
DISTRIBUTOR
SPARK PLUGS
FRAME OF CAR - KNOWN AS "GROUND"

PLATE 14—DELCO CIRCUIT DIAGRAM FOR CARTERCAR 1914, MODEL 7

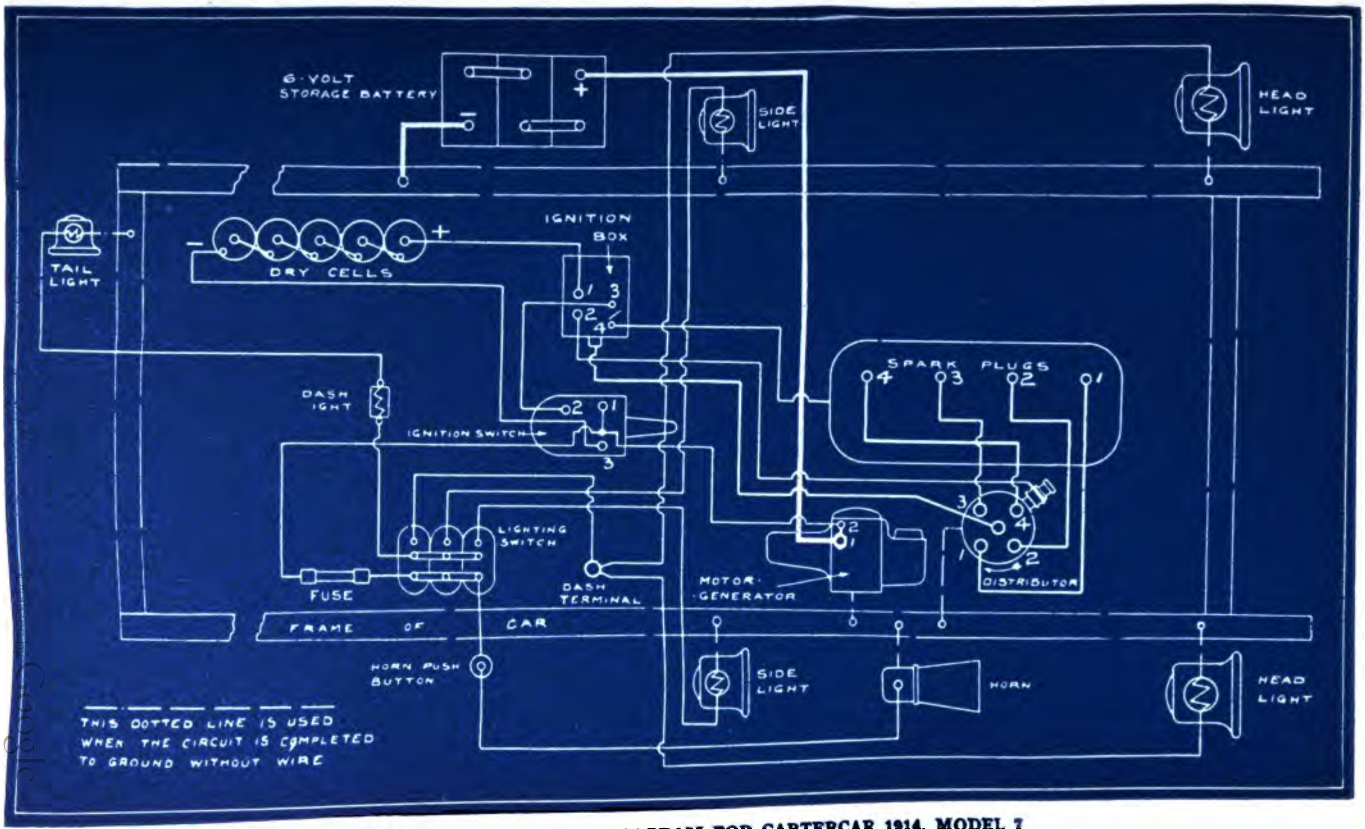


PLATE 15—DELCO WIRING DIAGRAM FOR CARTERCAR 1914, MODEL 7

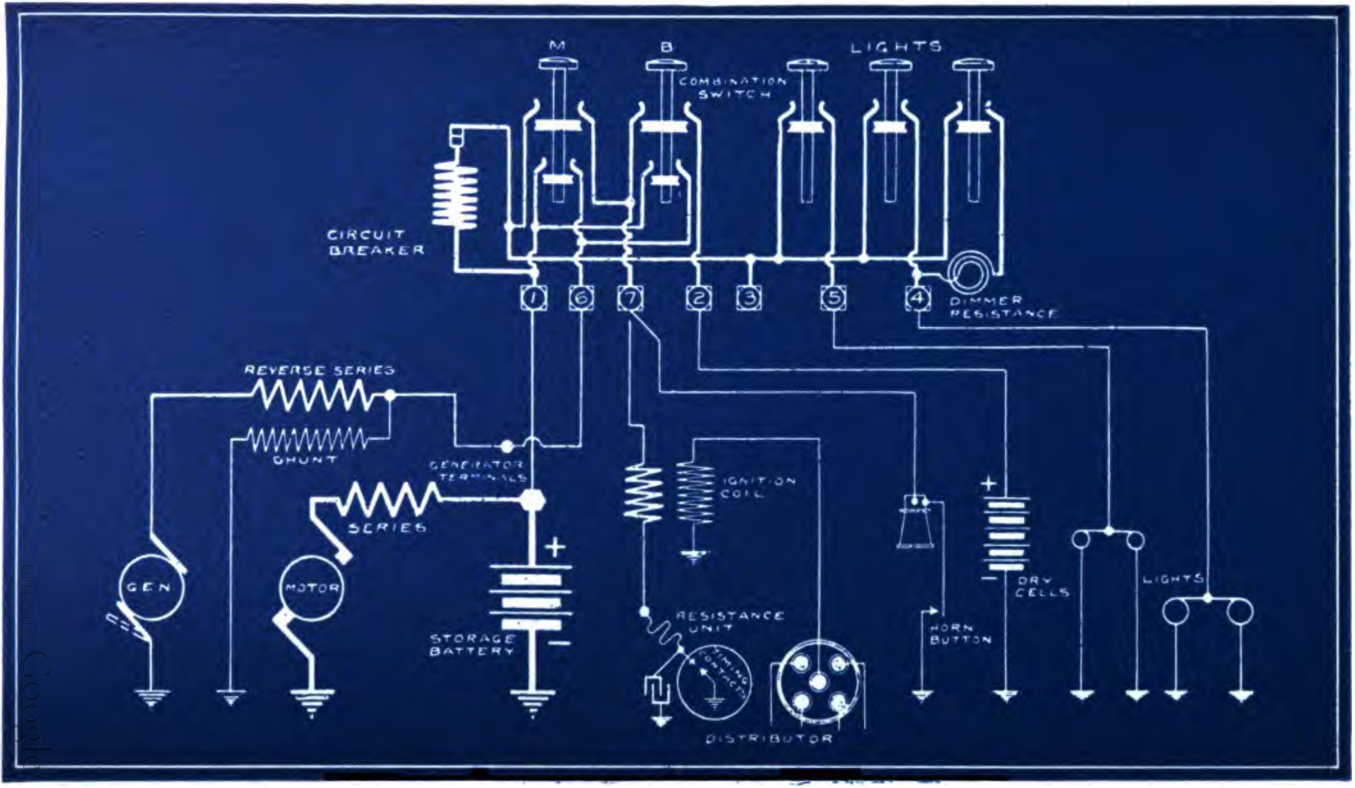


PLATE 16—DELCO CIRCUIT DIAGRAM FOR CARTERCAR 1915, MODEL 9

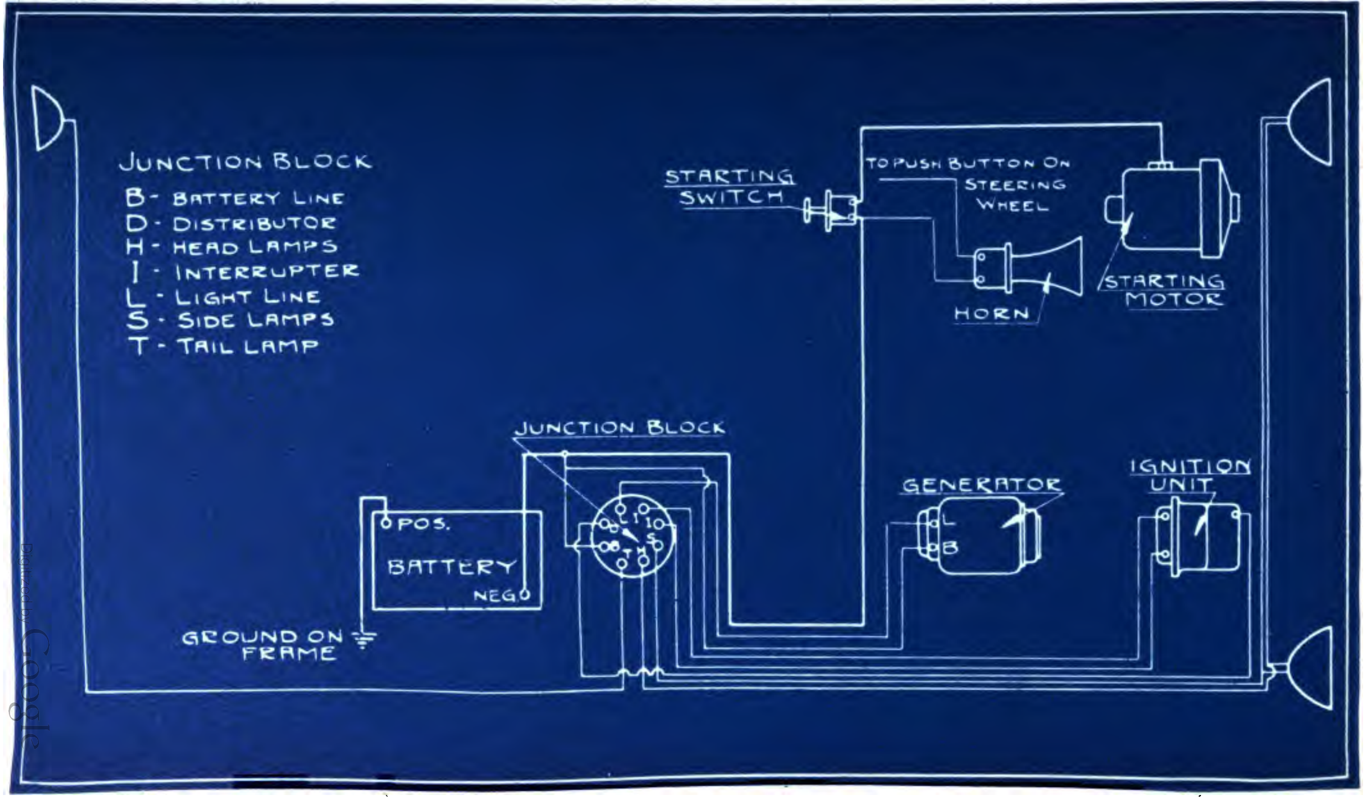


PLATE 17—WIRING DIAGRAM FOR CASE 1915 CARS, MODEL "30," WESTINGHOUSE SYSTEM

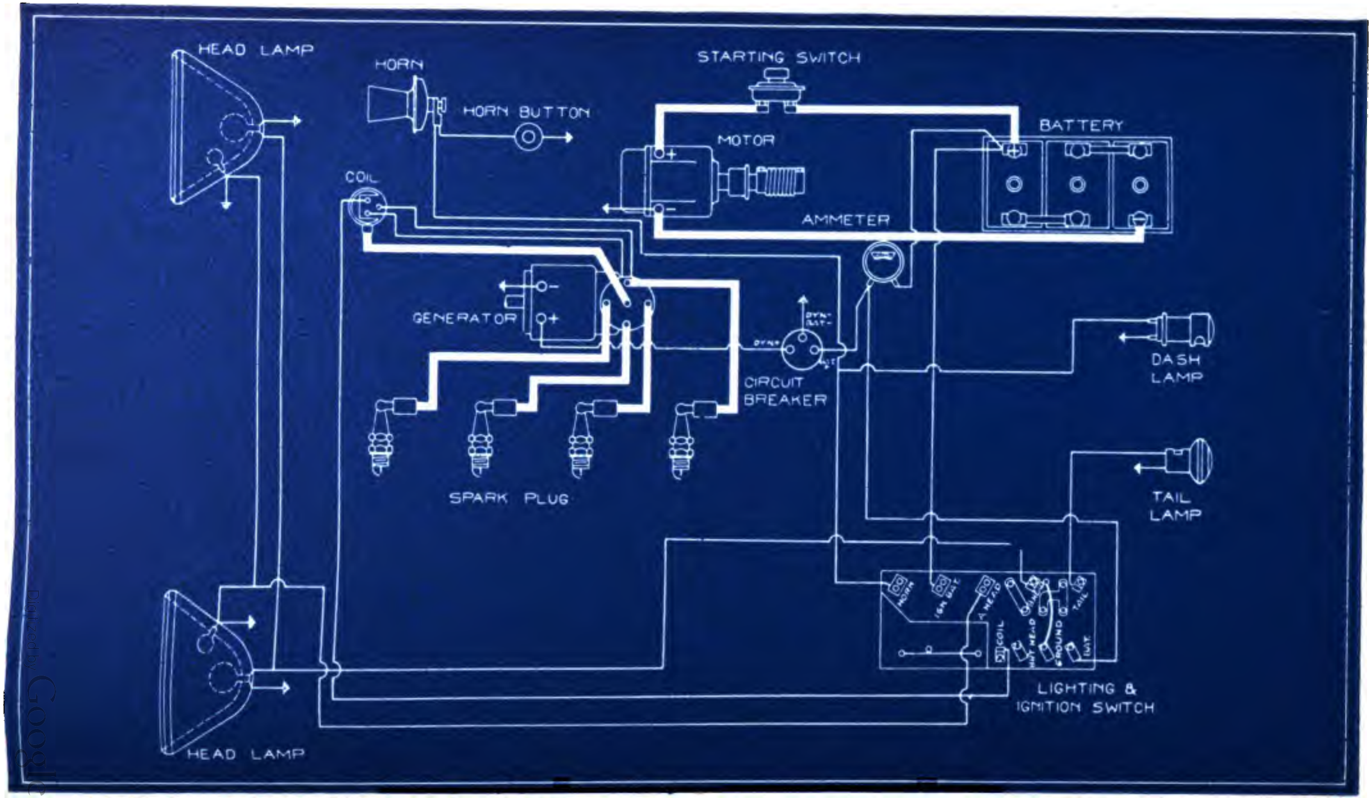


PLATE 18—AUTO-LITE WIRING DIAGRAM FOR CASE 1917 CARS

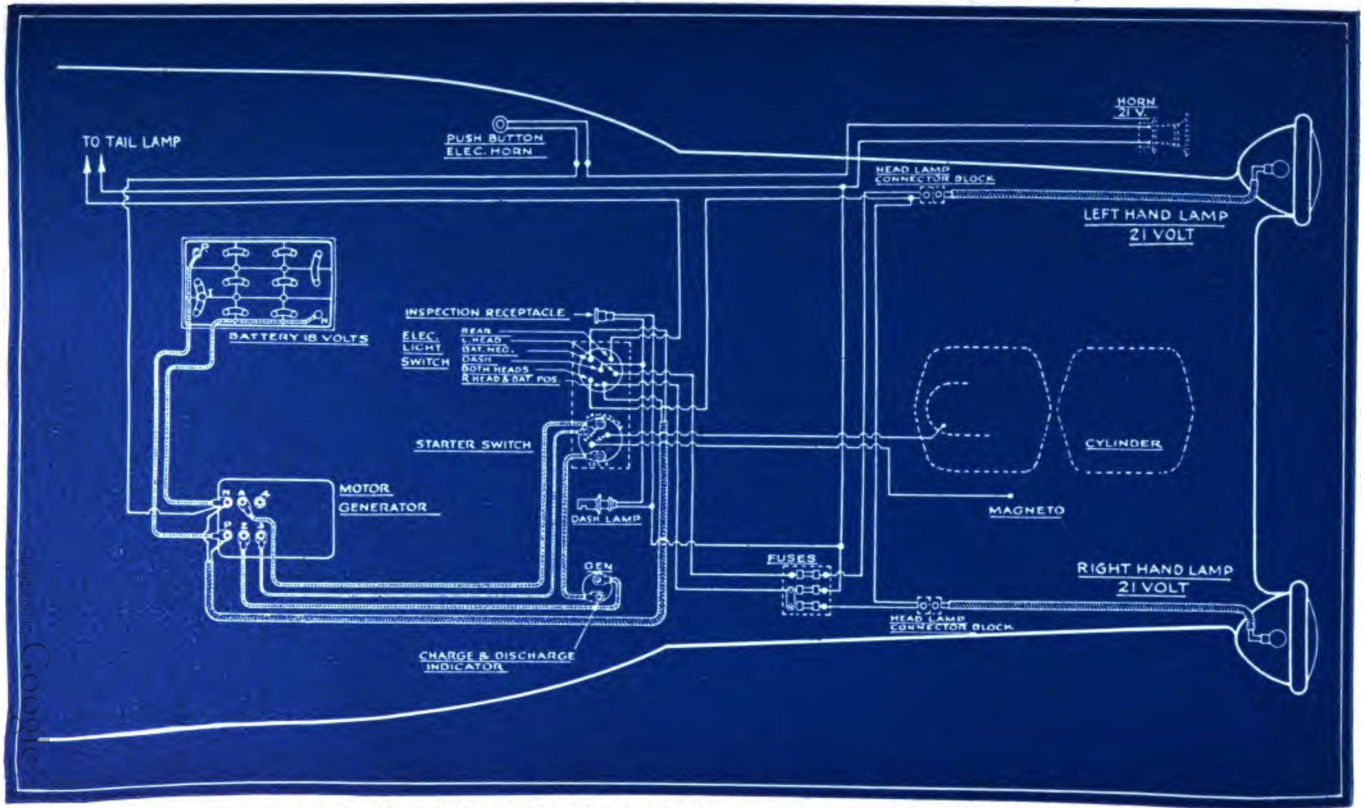


PLATE 19—WESTINGHOUSE WIRING DIAGRAM FOR CHALMERS 1915 CARS, MODEL 29

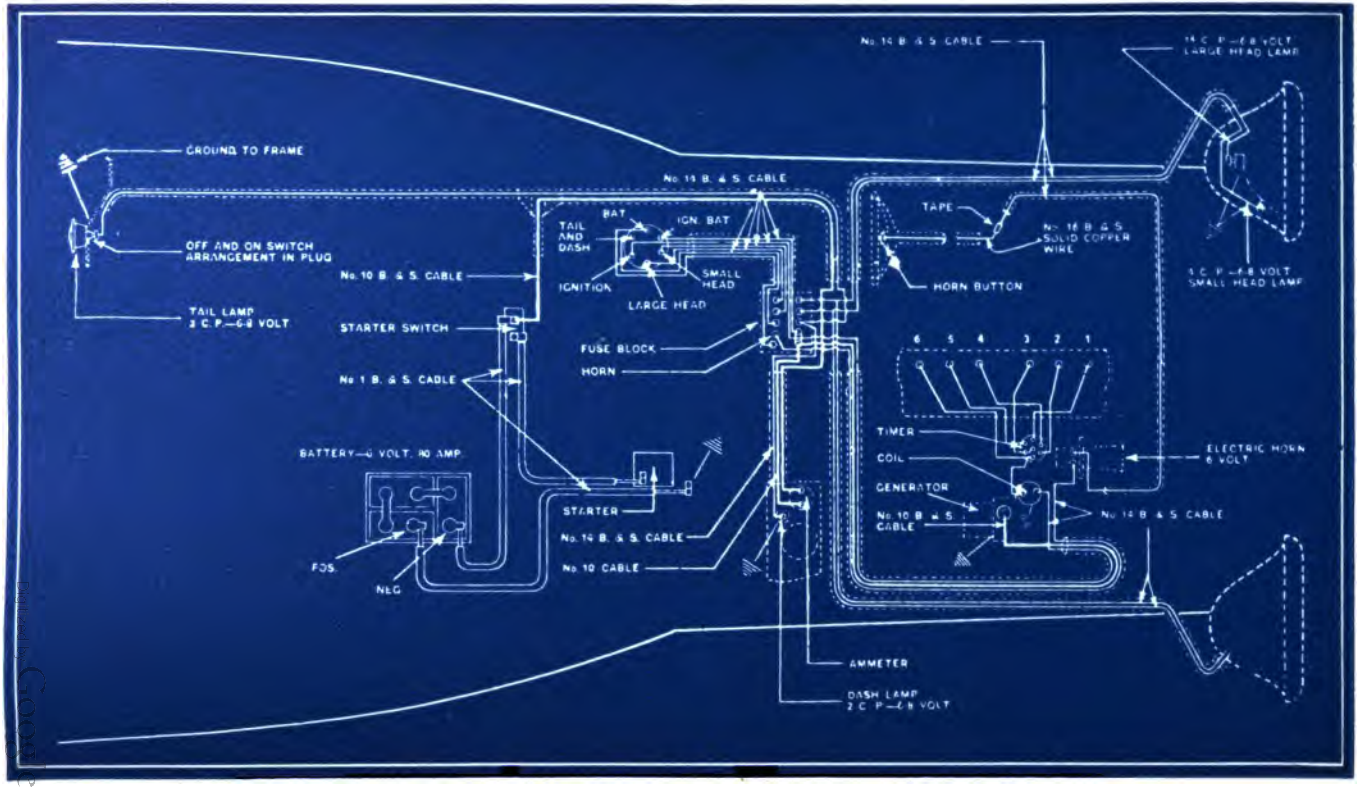


PLATE 30—WESTINGHOUSE WIRING DIAGRAM FOR CHALMERS 1917-18 CARS, MODEL 6-30

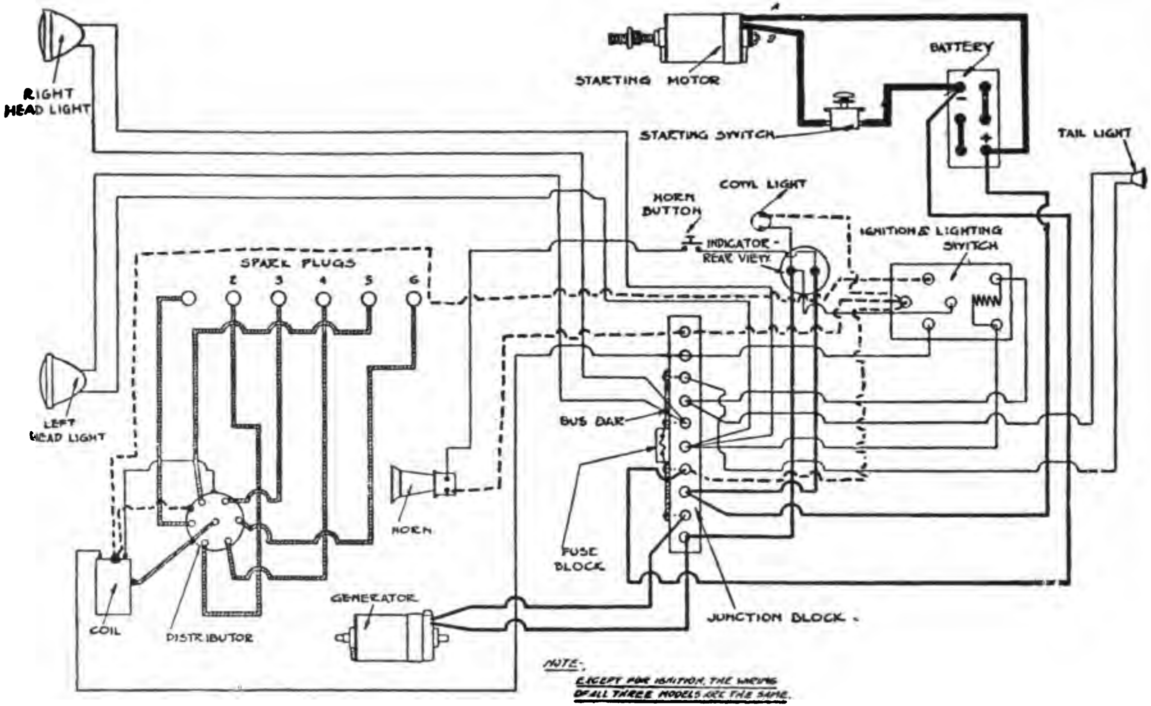
only the in-focus filaments will light. At the *out of focus dim* position all the lamps will light.

Hupp. General instructions covering failure of generator, starter, or lamp circuits apply as already given. Many other important factors might be mentioned such as open circuit, loose connections, blown generator fuse, corroded battery terminal, and brushes not seated properly. If the starting motor is damaged so that its removal is necessary, it should be removed by disconnecting one of the battery terminals and the two small wires *B* and *C* as shown on the diagram, Fig. 230. Next remove heavy cables *A* and *D* from the starting motor. The holding nuts on the motor can then be loosened to permit its removal. In replacing a starting motor, the pinion riding on the square shaft of the motor should be tested to see that it has a free sliding fit on the shaft. Do not use a file but see that all surfaces are perfectly clean and well oiled. The pinion must be guided over the shaft before the motor is pushed into place. Connect the new motor in accordance with the wiring diagram. Do not make storage-battery connections until all other connections have been made and while repairs are being carried out battery terminals should be protected.

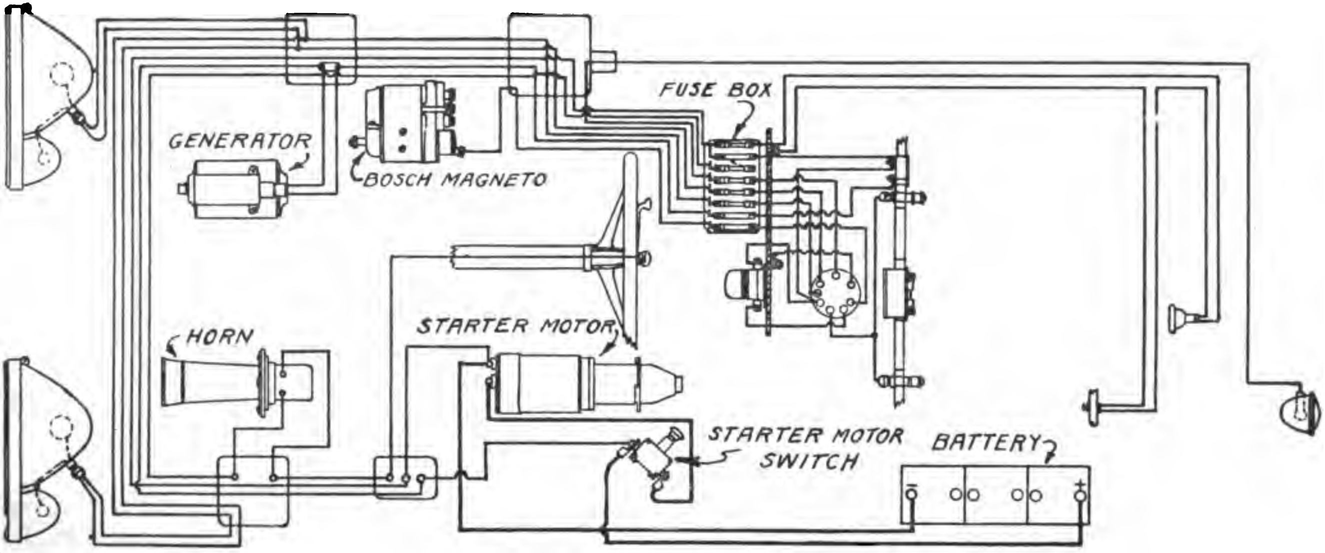
In case an inoperative starting motor is removed and a new one is not immediately available for installation, the car may be run with the hand-starting crank by proceeding as follows: Terminals on the end of cable *A* and the wires *B* and *C* must be connected together by binding tightly with bare copper wire and then thoroughly taping so as to form a good electrical joint that is well insulated. Secure the cables and wires to adjacent parts of the car with the aid of cord or insulating tape (not with wire) so that they cannot be chafed or otherwise injured by moving about while the car is running. The heavy cable *D* must be similarly taped and secured. The lighting system is then independent of the starting system. By making a study of the wiring diagram and carefully noting the different circuits, the starting circuit may be isolated from the lighting circuits on any car having a two-unit system. Before replacing a blown fuse always examine for grounds, short-circuits, or defective bulbs. Never replace a blown fuse with anything but another of the same capacity. If it is necessary to use the car before the trouble can be located, the grounded circuit can be left open by omitting its fuse. When all lights fail this is due to an open circuit between the battery and the fuse block. Examine the battery connections carefully and also connections of the cable *A* and wire *C* when they are connected to the starting motor; also examine the connections *E* at the ignition switch, *F* at the lighting switch, and the fuse block. If all of these connections are clean and tight, making good electrical contact, there is a broken wire between these points and the various circuits should be tried with the testing lamp.

Before making the usual tests for an inoperative generator see that the fuse protecting the field windings is intact. If this fuse has not blown and all connections are tight and properly made, remove wire from *B* which connects the generator to one terminal of the starting motor, and connect an ammeter in this circuit. Run the engine at a good speed, equivalent to 15 miles per hour or more. If the ammeter shows no current, while the commutator is bright, brushes bearing on it properly, and the battery connections are all right, test the armature and field windings with a lamp outfit to locate short-circuited windings. Do not remove the generator unless another is available for immediate installation. If it is necessary to run the car with the generator inoperative, the field fuse should be removed as a precaution against damage. To take the generator off, remove the circular cover plate from the front end of the chain case and take out the three bolts holding the generator to the rear side of the chain case. The driving chain should be supported through the opening at the front to prevent it from falling to the bottom of the chain case. It is not necessary to remove a pin connecting the links together. The chain may be tightened by loosening the three bolts mentioned and swinging the generator outward until the slack is taken up and then retightening the bolts.

Apperson. The generator on the Apperson system has a fuse protecting the field circuit, Fig. 231. Open connections between the generator and the battery will blow this fuse. It is located on the end of the generator adjacent to the terminals and is protected by an aluminum housing. To examine, remove the latter by taking out its two holding screws. The fuse is of the standard glass-tube type and may be lifted out of its clips with the thumb and finger. Do not attempt to pry a fuse out of its clips with a screwdriver



Wiring Diagram Showing Remy Ignition and Bijur Starting and Lighting Systems on 6-16, 8-16, 6-17, and 8-17 Apperson Cars
Courtesy of Apperson Brothers Automobile Company, Kokomo, Indiana



Bijur Starting and Lighting Installation on Winton Touring Six, Model 22-A
Courtesy of Bijur Motor Lighting Company, Hoboken New Jersey

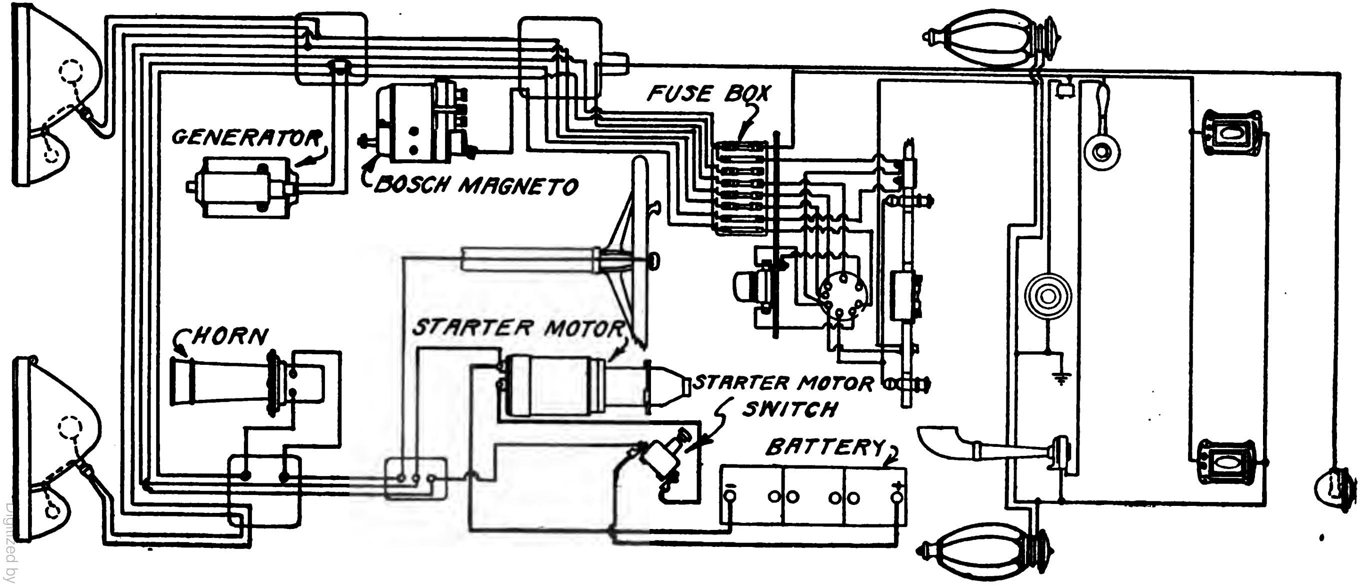
or other tool. Before replacing a blown fuse examine all connections and wiring to see that they are in good condition. The engine must never be run with the battery disconnected, as this will blow the generator-field fuse. These instructions apply to all generators equipped with field fuses, although the placing of the latter will naturally differ in other systems. Instructions for testing circuits are the same as those for other two-wire systems. There are no grounds except in the ignition system. Tests for inoperative generator or starting motor and instructions for the removal of either of these units are the same as already given.

Scripps-Booth. With the higher voltage battery supplied (12-volt) in the single-unit system employed on this car, the cells are of considerably smaller capacity (35-ampere-hour as compared with 80-ampere-hour on the Apperson and 120-ampere-hour on the Winton), so that if the car has been left standing for long periods with the lamps on, or is only run for short periods during the daytime, thus giving the battery no opportunity to become fully charged, it will not have sufficient capacity to start the engine. As the motor-generator (dynamotor) automatically reverses its functions in accordance with the speed at which it is being driven by the engine, the latter should not be run with the switch in the *on* position at speeds corresponding to a travel of less than 10 miles per hour. Under such conditions, as when the car is left standing with the motor idling slowly, or when driving at a very slow pace as in congested traffic, the switch should be placed at the *idle* position. Should the engine stall when the switch is at the *idle* position, it should be shifted immediately to the *on* position. For failure of the current indicator to work see instructions on this point on page 353. The indicator should never show *discharge* when the car is running above 12 miles per hour.

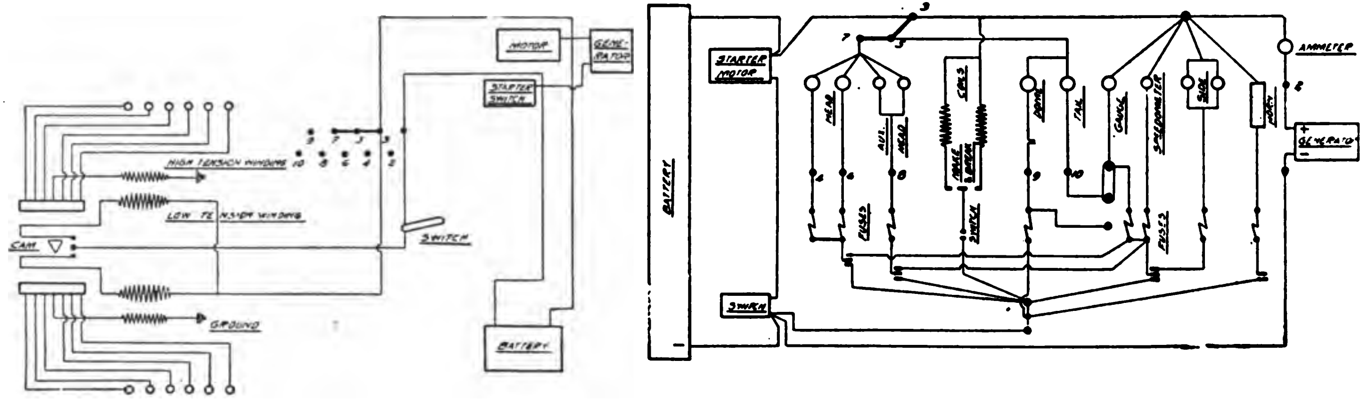
If necessity requires the operation of the car with the battery disconnected, disconnect the wires from the generator at the machine, as otherwise it is liable to injury. On the earlier Scripps-Booth models, Fig. 232, the engine should not be used as a brake in running down hill except in emergencies, but on later models, Fig. 233, this may be done without injury to the dynamotor by throwing the switch to the *off* position. By referring to the wiring diagram it will be noted that the shroud-lamp and cowl-lamp bulbs are of the double-contact type; all others are of the single-contact type. All must be 14-volt lamps, 15 c.p. and 4 c.p. in the headlights and 2 c.p. for the others.

Packard. Fig. 234 is the wiring diagram of the Packard twelve-cylinder motor, showing all connections for the ignition, starting, and lighting. Beginning at the left, are the double headlights and their connections, just back of them, the twelve-cylinder distributor and its connections to the twelve spark plugs, in groups of six. This distributor is illustrated in the preceding ignition section. It is practically two six-cylinder distributor units, each of which has its own induction coil, though both naturally must run synchronously, i.e., they are timed together, as the ignition alternates from one group of cylinders to the other. The secondary cables are represented by double lines which are shown part solid and part open, to distinguish them from other wires. To the right of the two coils, in the lower central part of the diagram, is the junction box, incorporating all the lighting-circuit fuses. Further to the right of this, the "switchboard" is a unit mounted at the head of the steering column of the car and which brings to one convenient point within easy reach, all the lighting as well as the ignition switches.

To indicate the heavy cables of the starting circuit, a double line is used with cross lines at short intervals. Two-wire connections are used throughout the entire system, barring the ignition. On the motor the high- and low-tension wiring is readily distinguishable by the difference in size, the low-tension wires having the thinner insulation. The low-tension current is carried in a complete two-wire circuit not grounded at any point. The high-tension current is grounded from the spark-plug body, through the motor to the coil bracket. The starting circuit may readily be traced by its heavy connections, and it will be noted that it is the shortest and most direct circuit in the system. Referring to the junction box, the strap shown connecting posts *A* and *B* is used in this way in all states the laws of which allow direct control of the tail light from the driver's seat. With this arrangement, the dash and tail lamps are in parallel and both are protected by the tail-lamp circuit fuse. For states requiring an independent tail-lamp circuit, such as Illinois, this strap is connected across posts *B* and *C;* with this arrangement, the dome-light fuse protects the tail light, while the



Bijur Starting and Lighting Installation on Winton Limousine Six, Model 22-A
Courtesy of Bijur Motor Lighting Company, Hoboken, New Jersey



IGNITION DIAGRAM

SIMPLIFIED DIAGRAM

Simplified Bijur Ignition, Starting, and Lighting Diagram for Packard "Twin Six", Models 2-35 and 2-25
Courtesy of Bijur Motor Lighting Company, Hoboken, New Jersey

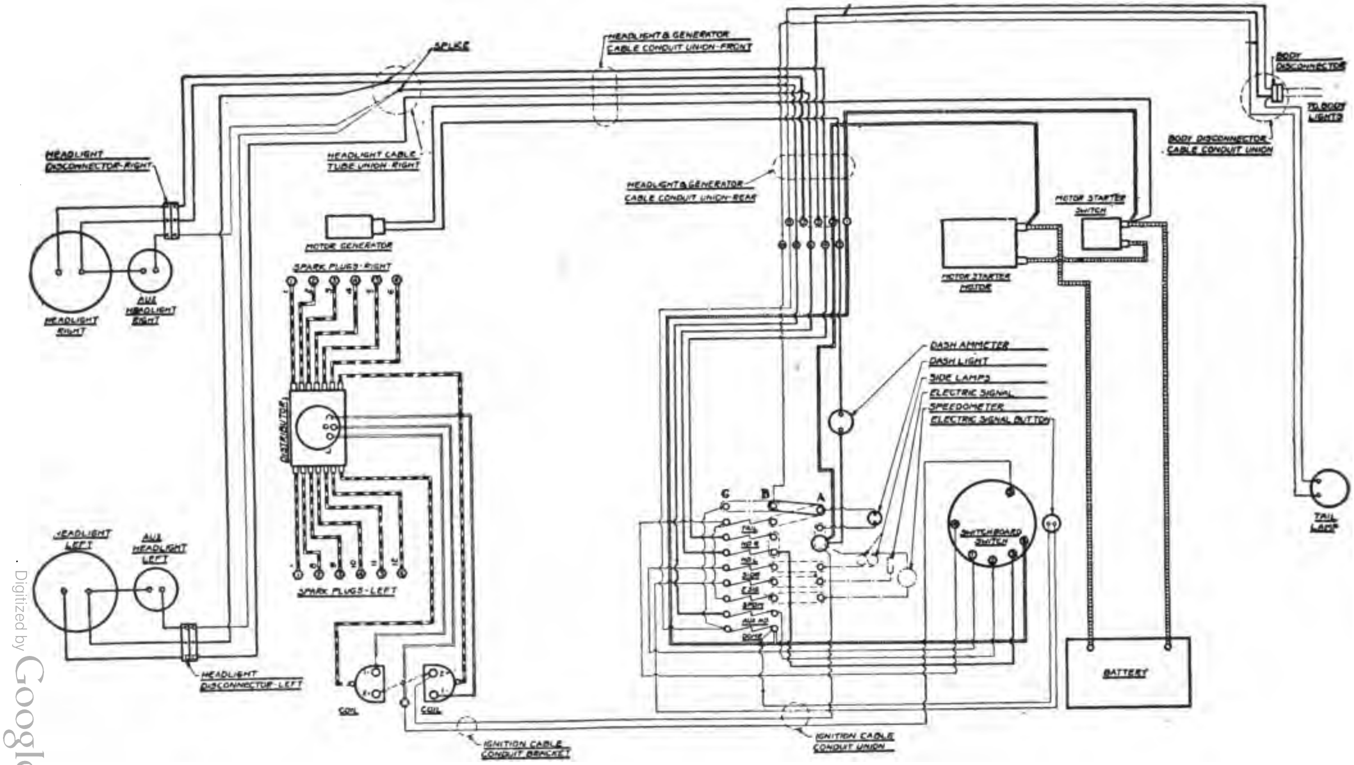


Fig. 234. Wiring Diagram of Bijur System for Packard "Twelves"

tail-light fuse protects the dash light. All wires are run in conduits, the various circuits enclosed in each conduit being indicated at different points on the diagram. High-tension wires from distributors to spark plugs are carried in tubes supported on the cylinder blocks.

BOSCH-RUSHMORE SYSTEM

Twelve-Volt; Two-Unit; Single-Wire

Generator. The bipolar shunt-wound type of generator is made in two sizes, one for driving from pump shaft, and the other for silent-chain or belt drive.

Regulation. *Ballast Coil Employed.* The regulation is the inherent type, using a bucking-coil winding in conjunction with a so-called "ballast coil" which automatically cuts the bucking coil in or out of the circuit, according to the resistance of the ballast coil. Mention has been made in Elementary Electrical Principles, Part I, that the resistance of certain metals increases greatly with an increase in their temperature. This is particularly the case with iron, and advantage has been taken of this fact in the Bosch-Rushmore generator. The ballast coil consists of a few turns of fine iron wire on a fluted porcelain rod. The bucking coil, which is simply a *reversed* field winding, has a polarity opposite to that of the winding employed to excite the field magnets. Consequently, when a current passes through it, the effect is to oppose the excitation of the field magnets. The bucking coil is connected as a shunt across the iron ballast coil, Fig. 148. The resistance of the bucking coil is considerably greater than that of the ballast coil when the iron wire is cold or only warm, so that at low engine speeds practically all the current generated passes through the shunt winding of the dynamo. However, the resistance of the wire increases at a constant rate with the current up to 10 amperes, after which it increases very suddenly owing to the heating effect of the current in the iron. Any current in excess of 10 amperes accordingly must pass through the bucking coil, which consequently tends to limit the output of the generator to that amount of current.

Starting Motor. *Method of Operation.* This is the series-wound bipolar type, as illustrated in section, Fig. 155, which shows the field windings as cut in half. As the illustration is to scale, the large size of the conductors in a series-wound field will be noted, this being necessary owing to the heavy current required to operate a starting motor. The starter pinion is mounted directly on the armature shaft without any intermediate gearing and the engagement of this pinion with the flywheel gear is automatic, as will be made clear by referring to Fig. 155, and to Fig. 165, showing the mounting of the Bosch starter on an automobile motor.

Refer back for a moment to the description of magnetic fields under Electrical Principles, Part I. See also the description of the action of a solenoid. It will be noted that every magnet has a magnetic circuit and that the lines of force comprising it are most numerous in close proximity to the poles of the magnet. In other words, the magnetic attraction is most intense at those points. The magnetic poles of the field of the Bosch starter are the metal projections each of which is held in place by two machine screws, top and bottom, as will be seen in the sectional view. It will also be plain that the armature of the starting motor is not directly in the magnetic field of these poles, and that it is held in this off-center position by the spring pressing against its shaft as seen at the left. The moment the switch is closed, however, and the field magnets are excited, the whole motor acts as a solenoid and forcibly pulls its armature into a central position against the spring, at the same time as it begins to revolve. This gives ideal conditions for meshing the starter pinion with the flywheel gear, as it is pulled against the latter and at the same time revolved, so that the moment its teeth correspond with spaces in the flywheel gear, it slips into engagement and begins to turn the engine over. As soon as the current is cut off by opening the switch, the spring returns the armature to its normal inoperative position and disengages the gears.

Starting Switch. There are two contacts on the starting switch, the first sending only a small amount of current through the starting motor, this being just sufficient to pull the armature into center and engage the gears, when a further movement of the switch sends the full current from the battery through the starting motor. This progressive movement of the switch and the two circuits between the battery and starting motor are shown in Figs. 235 and 236. It will be noted that the first movement of the switch throws the field of the starter in shunt with its armature, thus causing it to revolve slowly, while the further movement of the switch places the field in series. Fig. 237 shows the actual wiring diagram of the starting-motor circuit. In actual operation, the movement of the switch is practically instantaneous. No damage will result in case the switch is held down after the engine starts, as the moment the latter begins to fire, the load on the starting motor is greatly reduced and the current consumption decreases to a point where the field coils no longer have sufficient pull to overcome the spring on the armature. The pinion on the shaft of the latter is automatically disengaged from the flywheel gear and the motor will only idle slowly, owing to the armature being off center.

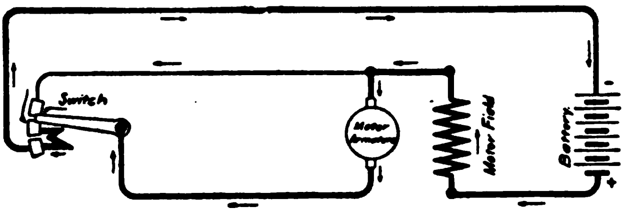


Fig. 235. Wiring Diagram for First Part of Downward Movement of Bosch Switch Pedal

Instruments and Protective Devices. A standard double-reading ammeter is supplied. The normal charging rate is approximately 20 amperes with the car running 20 to 25 miles an hour or over.

In addition to the usual battery cut-out which is an essential feature of most electric lighting and starting systems and will be found on most cars so equipped, whether it is specifically mentioned in the description of the various systems or not, a ballast coil is inserted in the charging circuit. This is similar to the ballast coil used in the regulation of the generator. This ballast coil is controlled by the left-hand button of the switch (installation on Mercer cars), and its function is to prevent overcharging of the battery. By

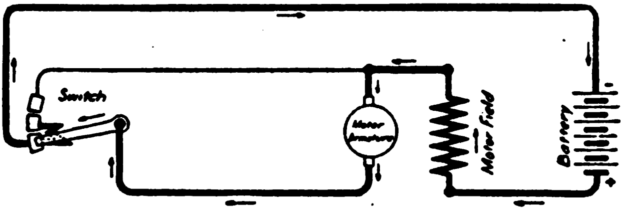


Fig. 236. Wiring Diagram for Circuit When Switch Pedal Has Completed Downward Movement

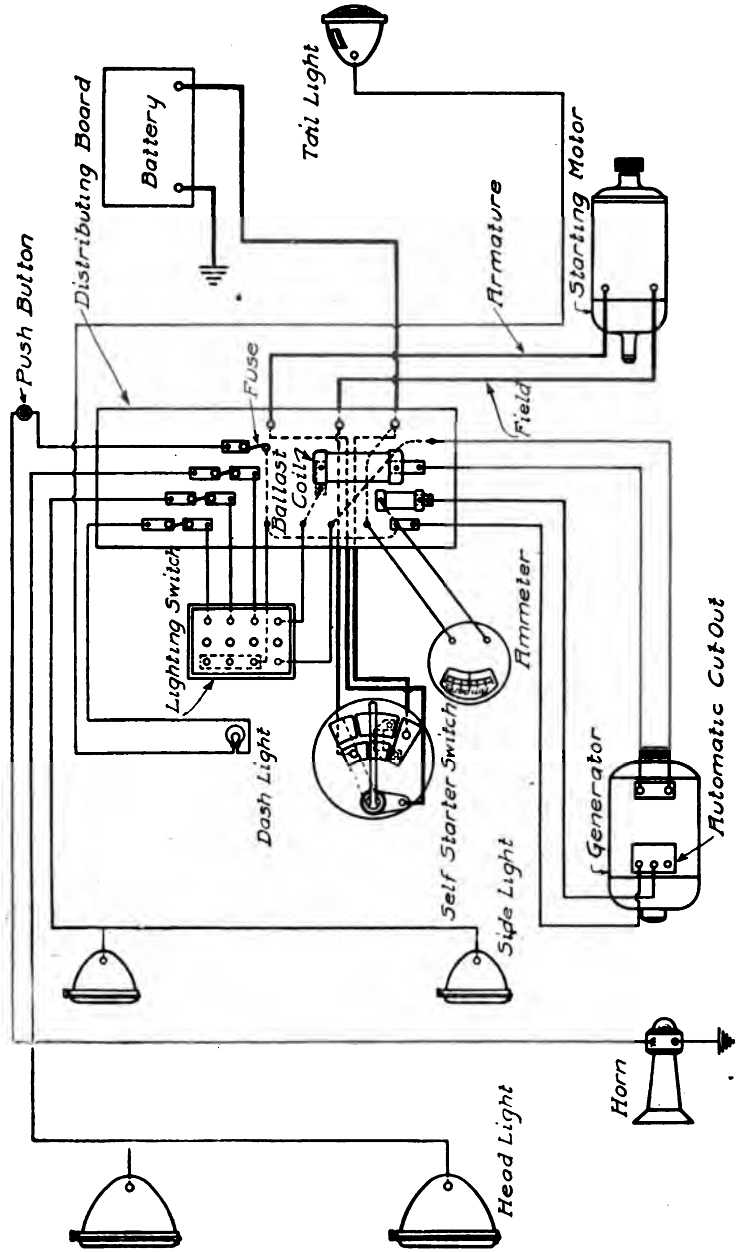
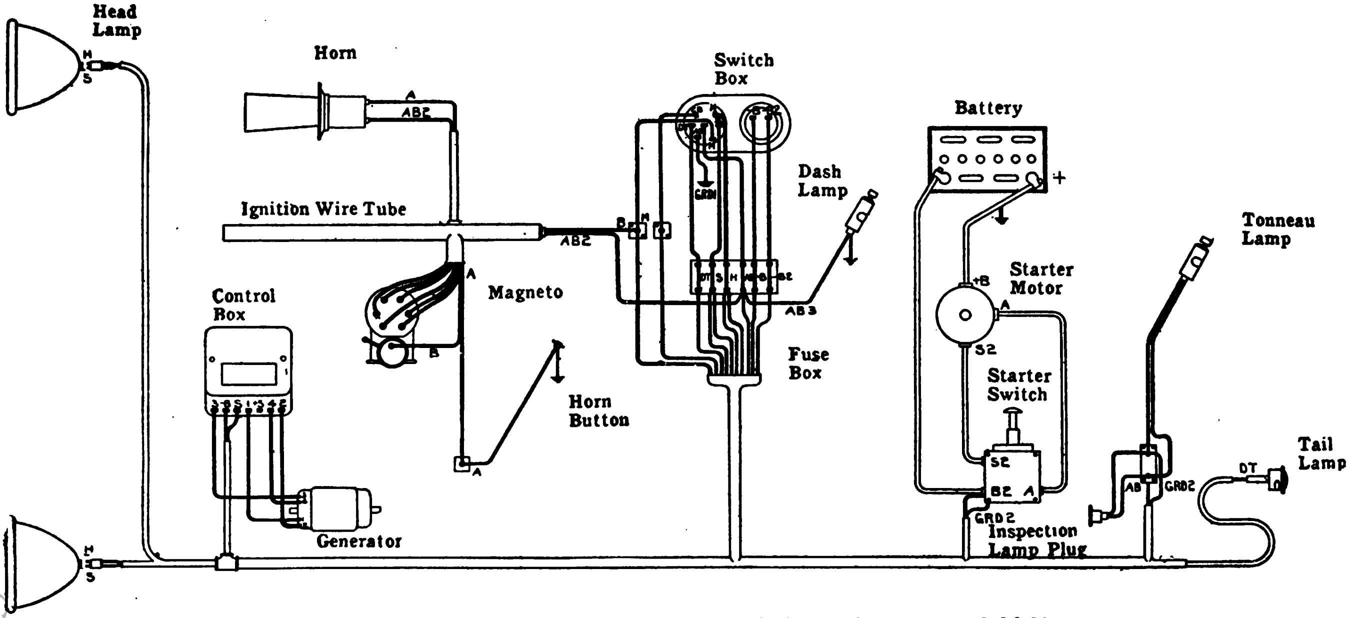


Fig. 237. Wiring Diagram for Bosch-Rushmore Starting System on a Mercer Car

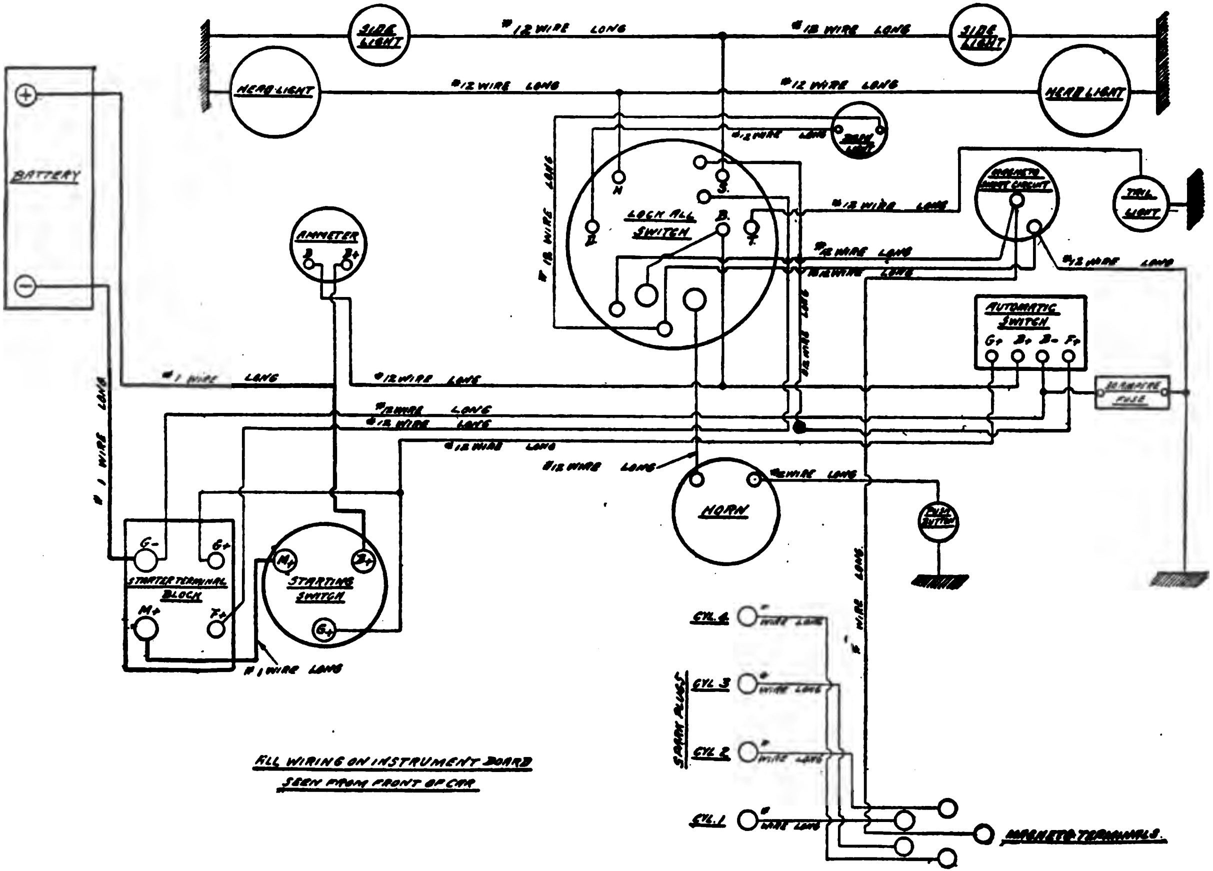
putting it in the circuit the charging rate is reduced to 5 amperes. Where a great amount of day running is done, it is recommended that the ballast coil be left in circuit. All circuits, except starting motor, but including field coil of generator, are fused.

Wiring Diagram. The various circuits of the single-wire system, as employed in the Mercer installation, are shown in Fig. 237. The automatic cut-out for the battery circuit is mounted on the generator. Ground connections are not indicated in every instance, as in the case of the generator and the starter they are made within the apparatus itself, and this is also the case with the lamps, which are known as the single-contact type. The latter are employed in all single-wire systems. In this case, they must be 12-volt bulbs as six cells of battery are employed. In making lamp replacements, only bulbs of the proper type, i.e., single or double contact, depending on whether the system is one- or two-wire, and of the proper voltage must be used. This, of course, applies to all electric systems, as, where a 6-volt bulb is placed on a 12-volt system, it will be burned out immediately. A 12-volt bulb on a 6-volt circuit will burn very dimly, so that when only one headlight burns brightly the voltage of the dim burning bulb should be ascertained before looking for trouble elsewhere. If the manufacturer's label has disappeared from the bulb, it can be tested with dry cells, starting with four in series which should make a 6-volt bulb burn brightly, and increasing to eight in series for a 12-volt bulb.

Instructions. *Battery Charging.* With all lamps on, the lighting equipment consumes about 12 amperes; the side and tail lamps together take about 3 amperes, so that when the ammeter reading shows a consumption in excess of these figures for the conditions given, the usual tests should be made for short circuits or grounds. The latter will be the case also when the ammeter shows any *discharge* reading with all lamps off. Any discharge under such conditions is *leakage.* However small it may be, it should be investigated at once, as it will run the battery down. The trouble may consist of a short circuit in one of the lighting circuits or it may be due to current flowing back through the generator caused by the failure of the cut-out to work properly. In case the lamps burn dimly when the generator is at rest, it indicates that the charging rate is not sufficient to keep the battery up. This may be caused



Bosch-Rushmore Ignition, Starting, and Lighting Installation on the Marmon, Model 34
Courtesy of Nordyke & Marmon Company, Indianapolis, Indiana



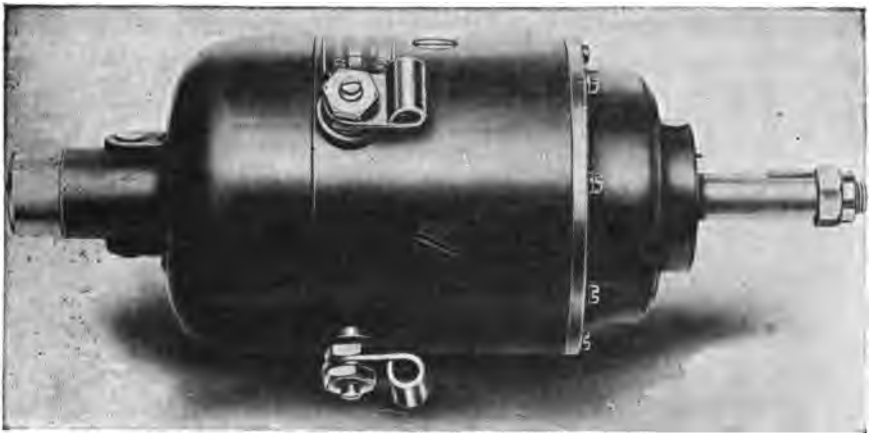
Bosch Ignition and U. S. L. Starting and Lighting Installations on the Mercer, Series 22-70
Courtesy of Mercer Automobile Company, Trenton, New Jersey

by a great deal of night running with the ballast coil in the charging circuit, as the charging rate is then only about 5 amperes. In the majority of instances, however, it will be found, probably, that the battery itself is responsible. For instructions on battery maintenance, see end of this article.

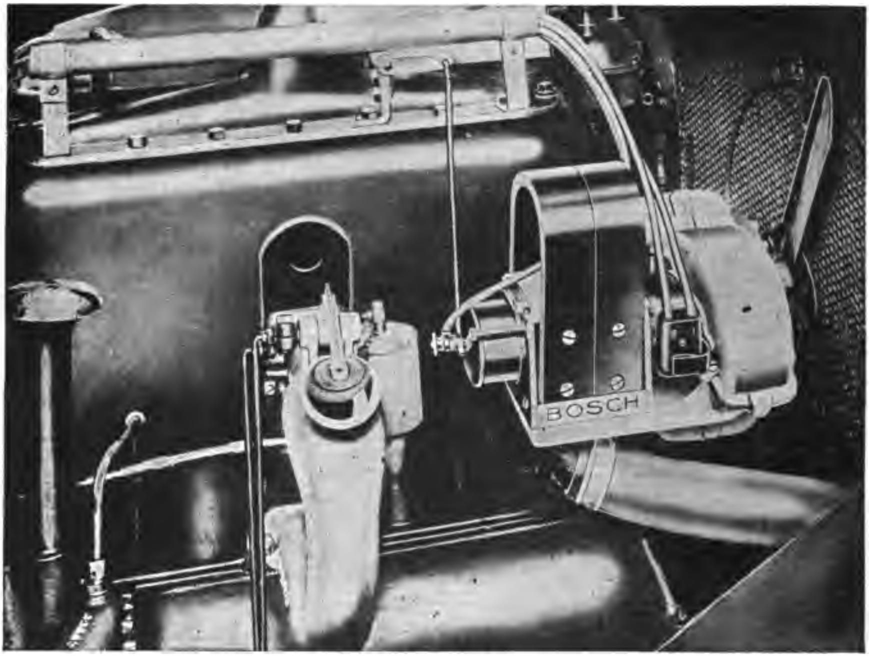
The battery furnished on the Mercer has a capacity of 120 ampere-hours. The starting motor takes approximately 200 amperes for its operation which, with the engine in good condition, should not consume more than 10 seconds for each start. To replenish the current consumed by starting twelve times in a day, or say a total of two minutes' operation of the starting motor at the 200-ampere rate, the engine would have to run only about half an hour at the average charging rate of 15 amperes. With the current consumed by the lamps, based upon their use for 5 hours per night, plus the natural deterioration losses of the battery, drop in efficiency through switches, contacts, and wiring, approximately two hours of daylight running would be required to keep the battery fully charged. Night running can be disregarded where battery charging is concerned, as the total consumption of the lamps is practically the equivalent of the average charging rate. An undue brilliancy of the lamps would indicate a battery wire off or loose and should be investigated.

Fuses. When ammeter shows no reading of charging current with the engine running, the most likely place to look for the trouble is the fuse protecting the generator field circuit. (This applies to all generators so equipped.) The field fuse of the Bosch-Rushmore generator is located on the distributing board, and it may be tested by short-circuiting the ends of the fuse cartridge with a pair of pliers, a screw driver, or other piece of metal. In case the ammeter then registers a charging current, the fuse has been blown out and should be replaced with another of the same type and capacity. As all circuits, except the starting motor, are fused, a similar test can be carried out in case of the failure of any of them. The blowing of a fuse is usually due to a short circuit, and before replacing it, the reading on the ammeter should be noted when the fuse terminals are short-circuited with the pliers, the generator being idle. A short circuit will be indicated by the needle of the ammeter moving sharply to the limit of its travel on the scale. The use of the testing lamp for finding short circuits is given in connection with the instructions under Auto-Lite, Delco, Gray & Davis, and other systems.

Gear Meshing. Faliure of the starting motor to operate will be due to an exhausted battery in the majority of instances, but on cars that have seen considerable service, it may be caused by a settling or distortion of the frame resulting in binding of the gear teeth too tightly. This may be corrected by readjusting the mounting of the starting motor in its supporting cradle so that the gears mesh quite loosely. It should always be possible to push the gears into mesh by hand without any effort. Unusually slow operation of the starting switch may also cause failure of the starting motor to operate properly. The first contact of the switch places a small resistance in the circuit and too long a delay may overheat this resistance to such an extent as to burn it out. Over-rapid operation of the switch may also cause failure to start as the gears are not allowed to mesh. This will be indicated by their clashing and by the spinning of the starting motor. The switch should be given a comparatively slow but steady movement from first to second contact.



TYPICAL BOSCH RUSHMORE STARTING MOTOR
Courtesy of American Bosch Magneto Corporation, Springfield, Massachusetts



TYPICAL BOSCH MAGNETO INSTALLATION
Courtesy of American Bosch Magneto Corporation, Springfield, Massachusetts

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART V

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES—(Continued)

DELCO SYSTEM

Six-Volt; Single-Unit; Single-Wire

Dynamotor. The dynamotor is usually referred to as a motor-generator, though it is actually a generator-motor, i.e., a dynamo-motor which has been shortened to dynamotor. This term has been adopted by the Society of Automobile Engineers to designate the combination unit in question. A motor-generator as employed for transforming alternating current to direct current consists of two separate units: a motor driven by alternating current and a dynamo generating direct current, mounted on the same bed, and with their armature shafts directly coupled.

The Delco single-unit machine consists of two separate field windings and two independent armature windings, the latter being connected to separate commutators at either end of the shaft. In combination with this is an ignition timer and distributor mounted at the generator end and driven from the armature shaft through spiral gears. The generator is driven from the pump shaft of the engine through an over-running clutch which permits the armature to run free when the unit is operating as a starting motor. At the starter end, the armature shaft carries a small pinion meshing with the larger unit of a pair of sliding gears, the smaller of which is adapted to slide into engagement with the gear ring of the flywheel. This arrangement is shown clearly in Fig. 238; it provides a double gear reduction between the starting motor and the engine. In the smaller of the two sliding gears is incorporated an over-running clutch which releases the starting motor from the engine in case the latter should be speeded up without disengaging the starting gears, thus preventing damage to the starting motor by running it at an excessive speed.

Control. The necessary switches for putting the generator in circuit to charge the battery, and to cut it out of this circuit and put the starting motor in circuit with the battery to turn the engine over, are built into the machine and take the form of lifting brushes. Their operation is as follows:

To start, the ignition button on the switch panel on the dash is first pulled out. This connects the storage battery with the ignition circuit and with the armature of the dynamotor through a resistance which permits only a current of small value to pass. This current *motorizes* the generator and causes its armature to rotate slowly, giving it just enough speed to facilitate the meshing of the starting gears. The starting pedal is then depressed and during the first part of its travel it serves to engage the gears, Fig. 238. Then it withdraws the pin *P*, Fig. 239, allowing the motor brush switch to make contact with the motor commutator. At the same time it causes the generator switch to open, thus cutting out the generator during the cranking operation. As soon as the motor brush makes contact, the full current from the battery passes through the series-

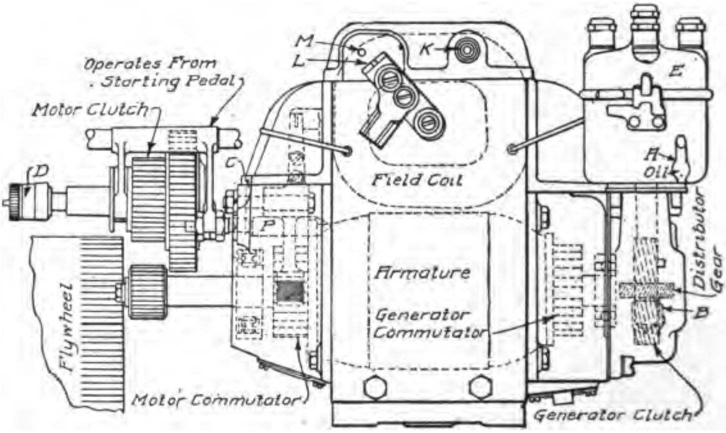


Fig. 238. Diagram of Delco Dynamotor for Single-Unit System

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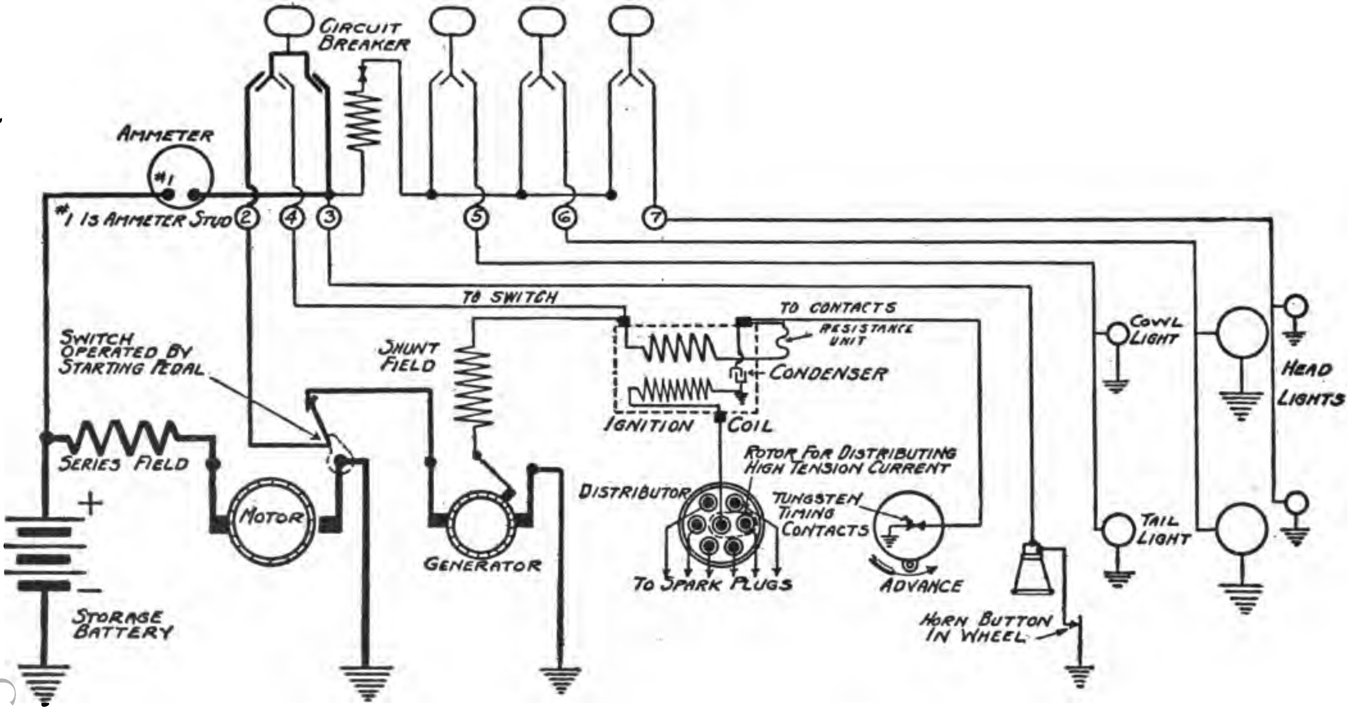
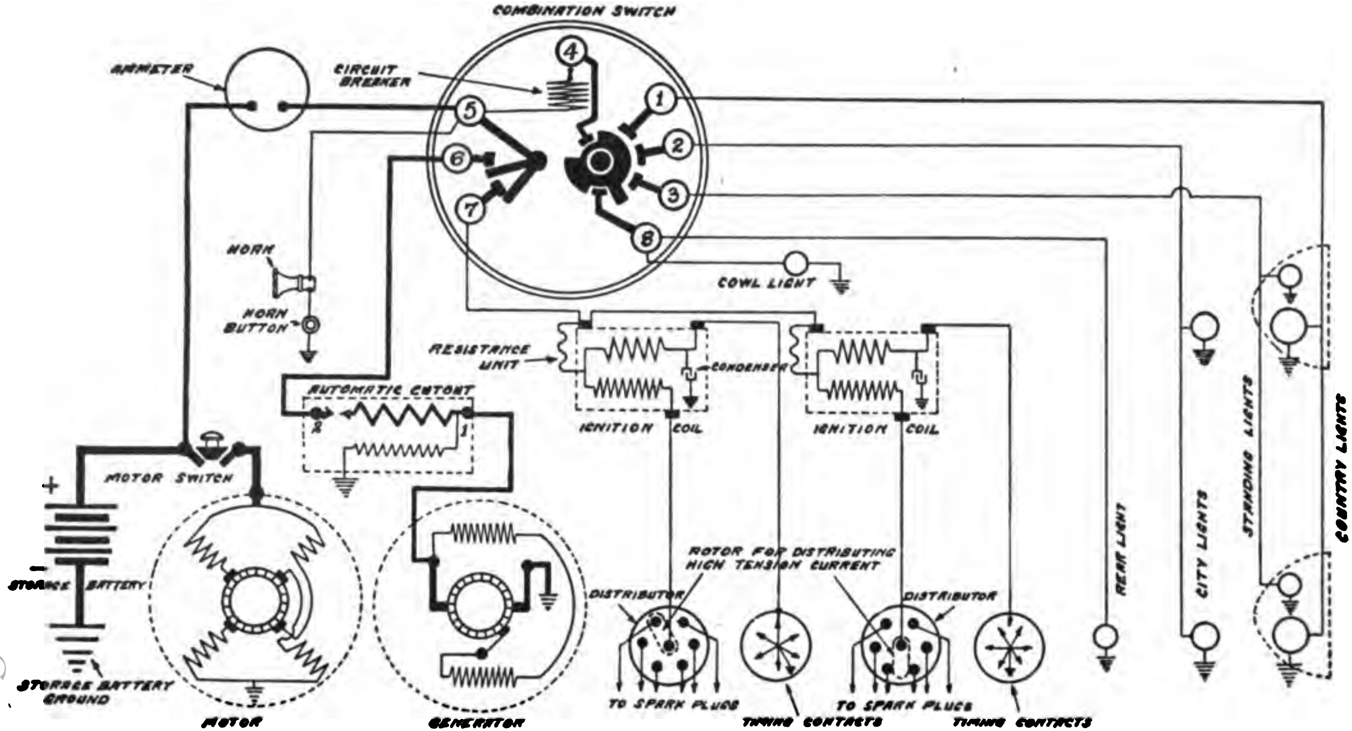


83	**Motor Generator**	**2142**	**Ignition Coil**
1066	**Combination Switch**	**12225**	**Motor Clutch**

Delco Starting and Lighting Installation on the Auburn, Model 6-44
Courtesy of The Dayton Engineering Laboratories Company, Dayton, Ohio



87	Generator
5715	Automatic Cutout
5136	Distributor
2123	Ignition Coil (2)
1085	Combination Switch
86	Motor
1965	Motor Switch
6064	Ammeter

Delco Starting and Lighting Installation on the Austin Twelve-Cylinder Model field winding of the motor element and through the corresponding armature windings, and sets the armature rotating at full speed.

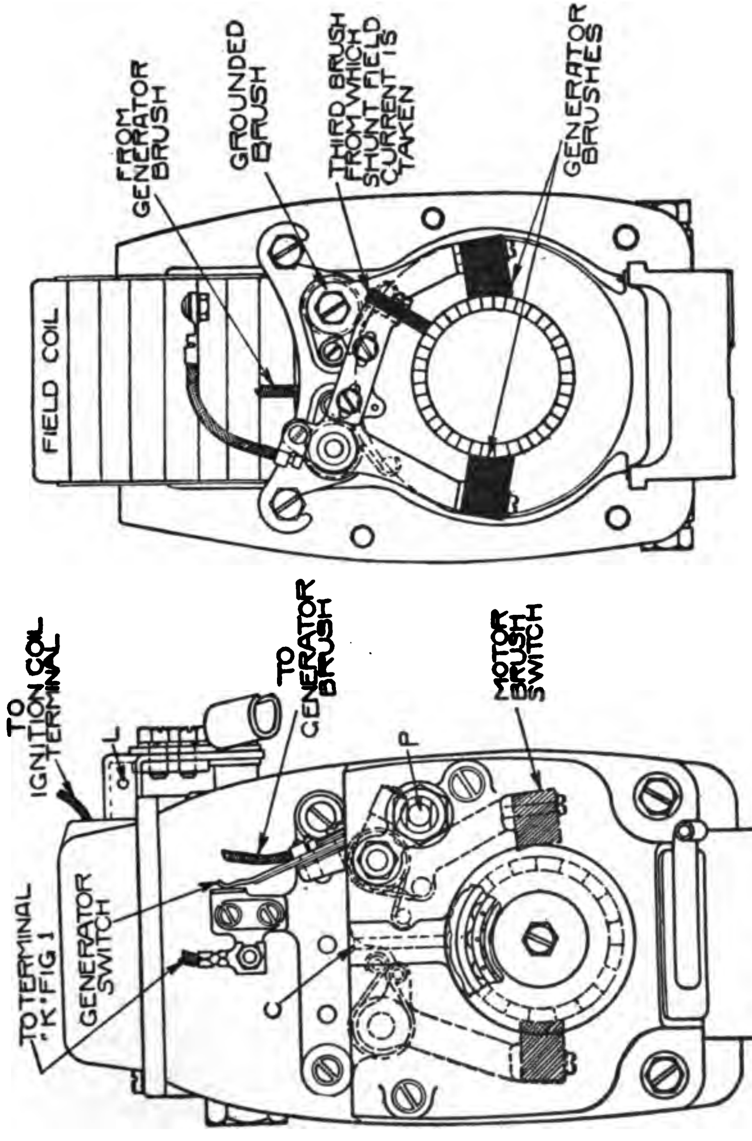


Fig. 239. Details of Brushes and Brush Switches, Delco Single-Unit System

The starter pedal is returned to the open position by a spring and as soon as it is released, the motor brush is lifted from its commutator and the generator switch is closed, thus cutting out the motor windings and connecting the unit to the storage battery as a generator. Charging begins when the engine reaches a speed corresponding to 7 miles per hour.

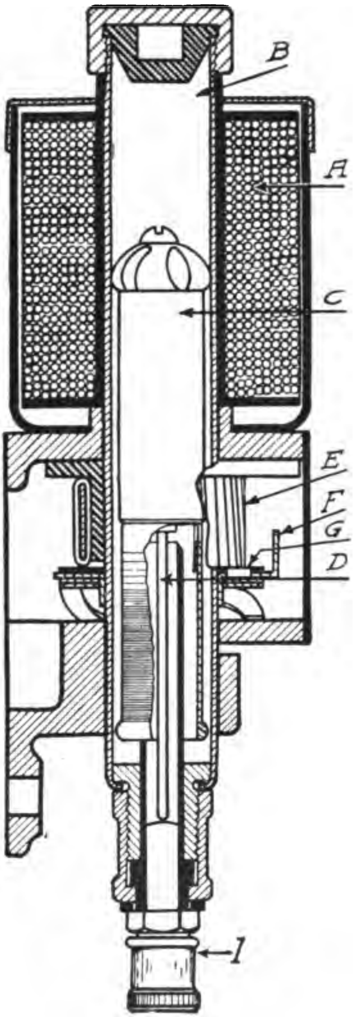
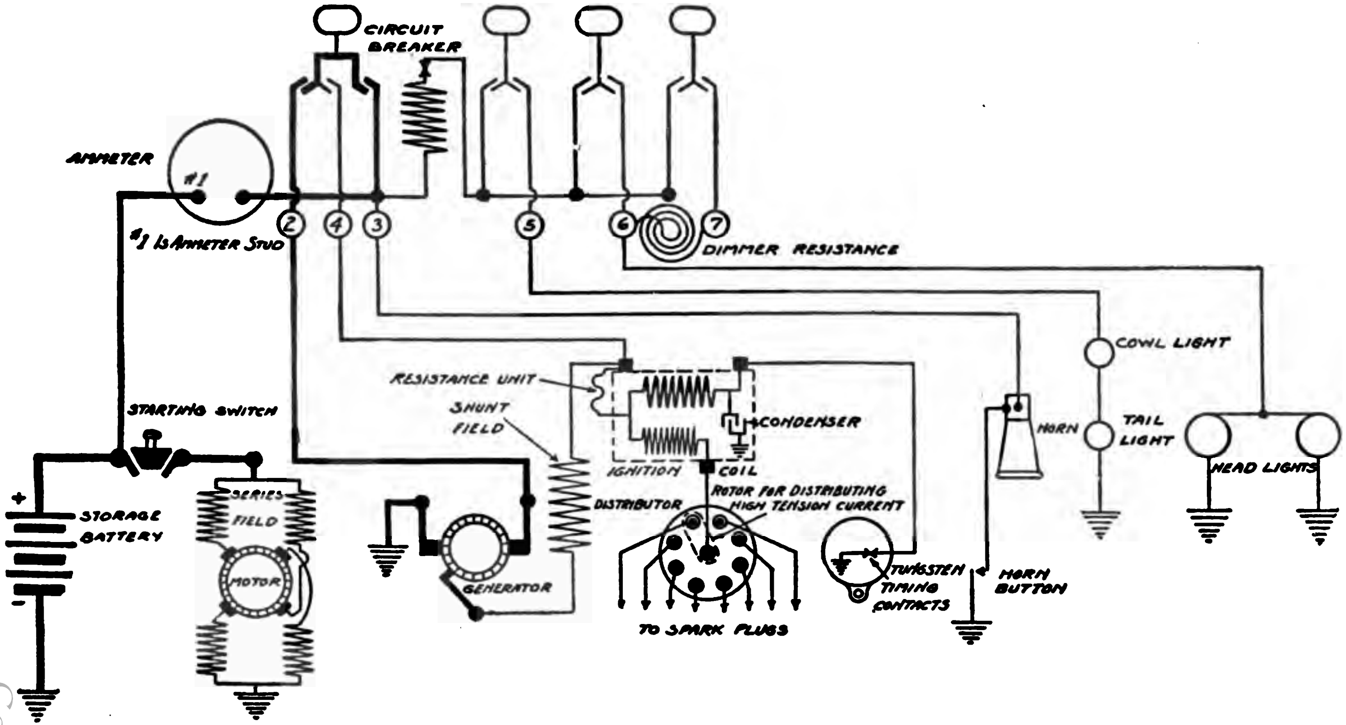


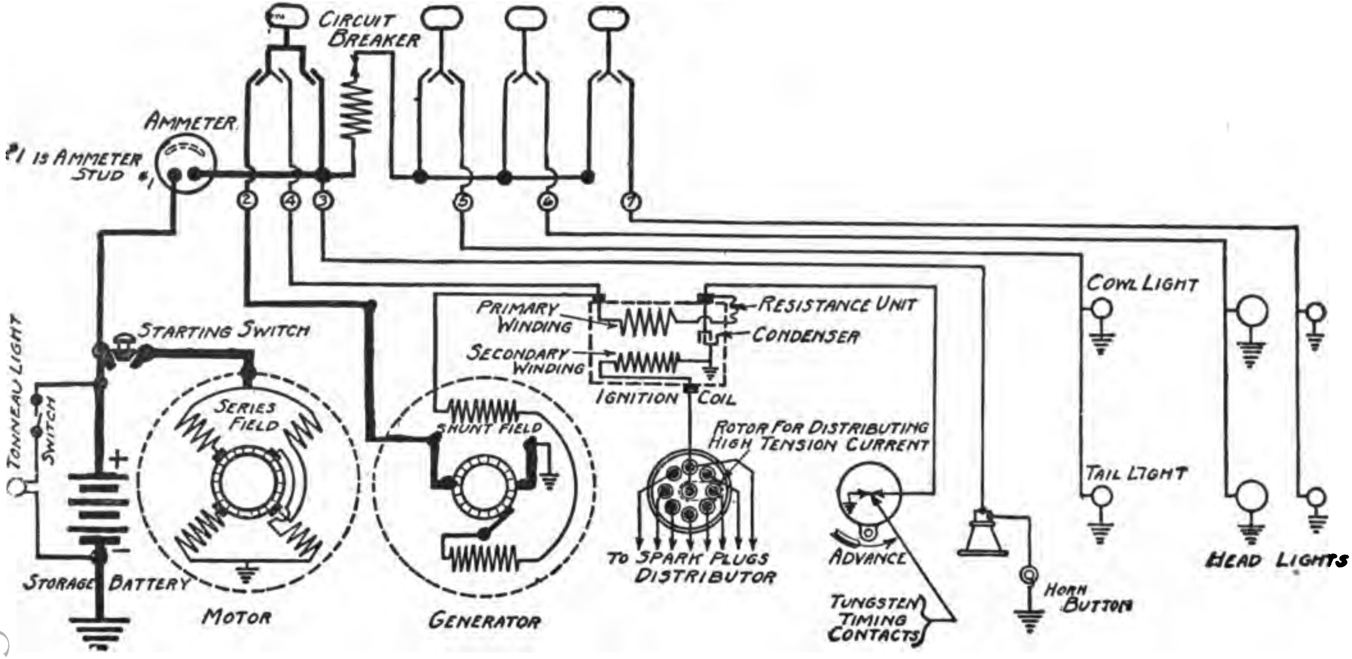
Fig. 240. Section Showing Delco Mercury-Bath Voltage Regulator

Regulation. *Constant-Voltage Control Type.* Of the four types produced the first employs a resistance variable in accordance with the speed. The regulator consists of a solenoid the core of which has a spool of resistance wire wound on its lower end, Fig. 240. This core or plunger *C* floats in a bath of mercury, and, in accordance with the depth to which it sinks in the mercury, more or less of the resistance wire is short-circuited by the mercury. The solenoid winding *A* is connected in shunt across the generator terminals so the current flowing through it and the magnetic effect exerted by it are always proportional to the voltage at the generator terminals. The resistance wire on the plunger of the solenoid is in series with the shunt-field winding of the generator. If there were no other forces than the buoyancy of the mercury and that of gravity acting upon the plunger it would remain at approximately the same height, but as the plunger is iron it is acted upon by the solenoid winding, the effect being to withdraw it from the mercury as the current through the winding of the solenoid increases, thus putting more and more of the turns of resistance wire on the spool in circuit. Hence, the greater the current flowing through the solenoid the greater will be the resistance in circuit with



91	Generator	1067	Combination Switch
5153	Distributor	1963	Motor Switch
2123	Ignition Coil	72	Motor

Delco Starting and Lighting Installation on the Cole, Model 860



113	Generator	1087	Combination Switch
5158	Distributor	72	Motor
2146	Ignition Coil	1963	Motor Switch

Delco Starting and Lighting Installation on the Cole, Model 880 the shunt-field winding of the generator. To overcome the effect of temperature variation on its operation which would cause the charging rate to be higher than intended at high temperatures, and *vice versa*, the solenoid is wound and connected in series with a resistance wire of special material having a negative temperature coefficient (i.e., whose electrical resistance decreases with an increase in temperature), so that the total resistance of the solenoid circuit remains the same regardless of temperature changes. With a few exceptions, such as the Olds 1915 Model 55, this method of voltage regulation is not employed on cars subsequent to 1914.

Bucking-Coil Type. This is the type of regulation usually referred to as *inherent* in that it is accomplished by the windings of the generator itself. The latter is compound wound but the series field has a reversed polarity, so that its effect is to oppose that of the shunt winding.

Mechanically Varied Resistance. - In this type the same principle as that employed in the first type described is used, i.e., that of weakening the generator field by increasing the amount of resistance in circuit with it in accordance with the speed, except that it is varied by mechanical means instead of electrical. The regulator resistance is in the form of a rheostat, the arm of which is controlled by a centrifugal governor driven from the shaft of the ignition distributor. As the weighted element of the governor expands under the influence of the increasing speed, it moves the arm of the rheostat over the contacts each of which represents an added resistance to the circuit.

Both the bucking-coil type and the mechanically varied type of regulation are employed in Delco systems installed on 1915 and subsequent cars, different models of the same make and the same year having different systems, so that instructions for their maintenance depend upon the system employed.

Third-Brush Method. As the voltage generated varies directly with the speed, it is evident that to maintain a nearly constant voltage with a variable speed, it becomes necessary to decrease the magnetic field as the speed increases. Since the magnetic field of the generator is produced by the current in the shunt-field winding, a decrease in this current as the speed increases will regulate the output. Bearing in mind that a current always produces a magnetic field, whether the latter is desired or not, the theory of this method of regulation will be clear from the following reference to Fig. 241. The full voltage of the generator is obtained from the brushes *C* and *D*. When the magnetic field from the pole pieces *N* and *S* is not disturbed by any other influence, each coil is generating uniformly as it passes under the pole pieces; the voltage from one commutator bar to the next is practically uniform all around the commutator. Therefore, the voltage from brush *C* to brush *E* is about 5 volts, when the total voltage between the main brushes *C* and *D* is 6½ volts and current at 5 volts' pressure is supplied to the shunt-field winding. This voltage is sufficient to cause approximately 1¼ amperes to flow through that winding.

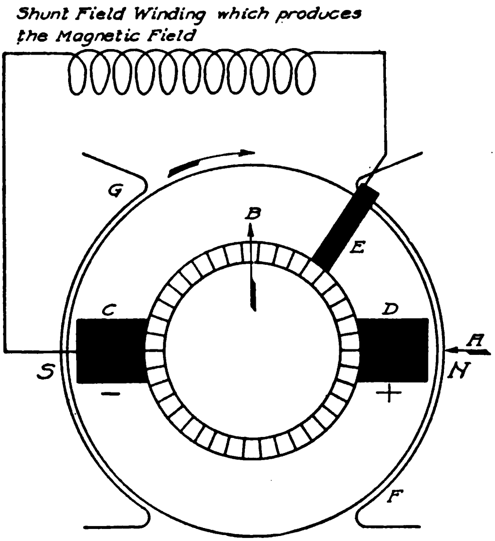
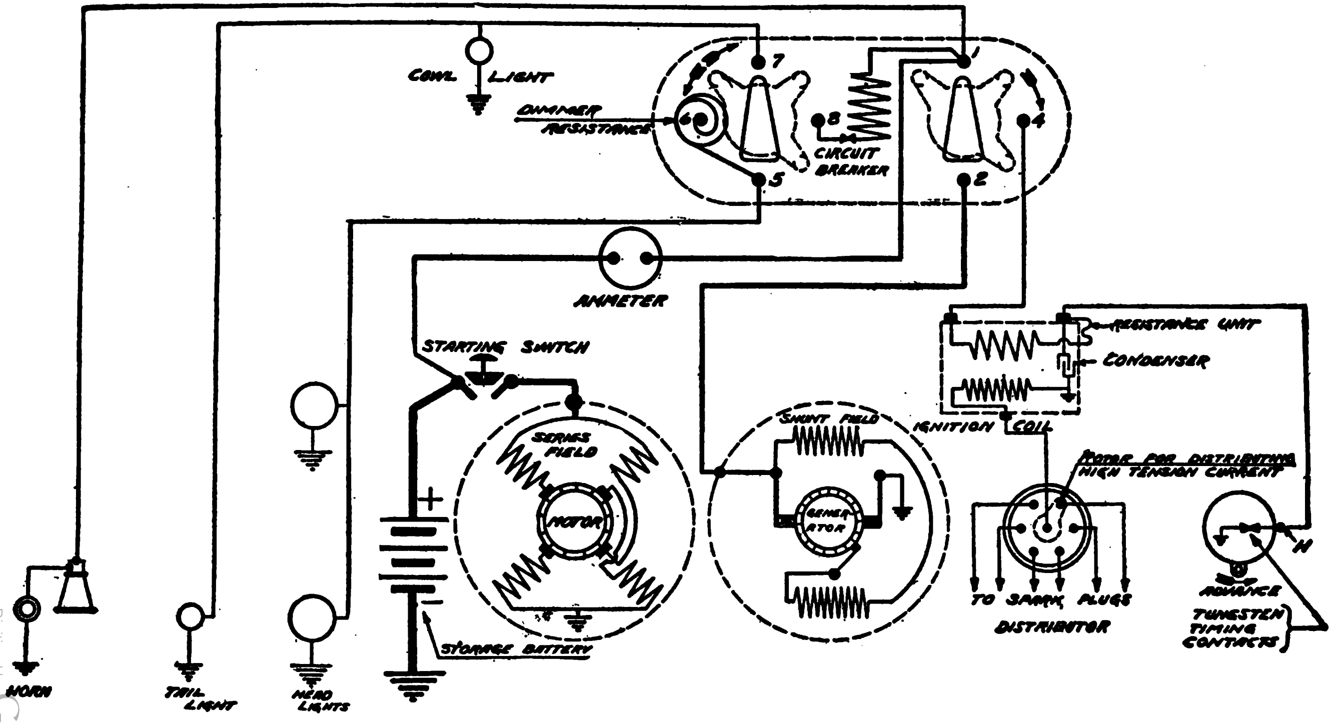


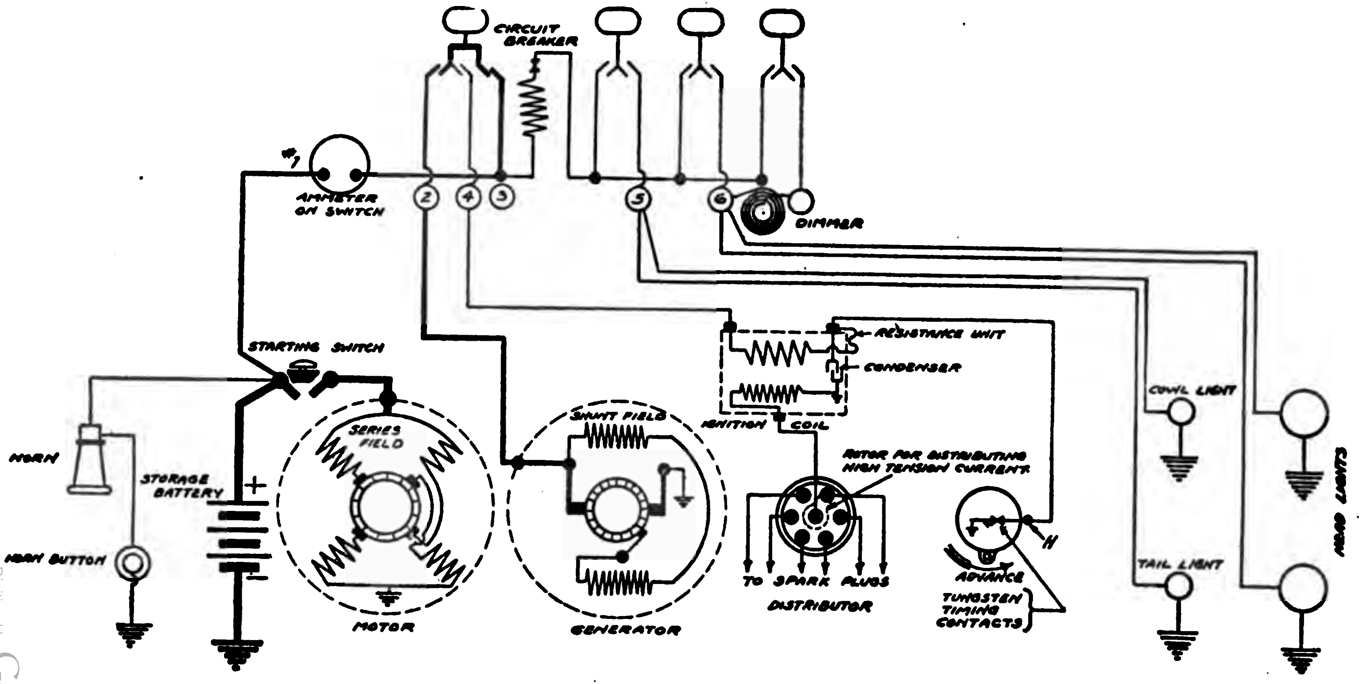
Fig. 241. Delco Third-Brush Regulator

As the speed increases, the voltage does likewise, charging the battery. This charging current flows through the armature winding causing a magnetic effect in the direction of the arrow *B* and the latter acts upon the main magnetic field, which is in the direction of *A*, with the result that the latter is twisted or distorted out of its original position, in much the same manner as two streams of water meeting are deflected from their original directions. This deflection causes the magnetic field to be strong at the pole tips *G* and *F*, and weak at the opposite tips, with the result that the coils generate a very low voltage while passing from brush *C* to brush *E* (the coils at this time are under the pole tips having a weak field) and produce the greater part of their voltage while passing from brush *E* to brush *D*. The amount of this variation depends upon the speed at which the generator is driven, thus decreasing the current supplied to the shunt field as the speed increases.



105	Generator	106	Motor
1078	Combination Switch	1964	Motor Switch
2139	Ignition Coil	6059	Ammeter

Delco Starting and Lighting Installation on the Davis, Models 6-H, 6-I, 6-K



114	**Generator**	**102**	**Motor**
1067	**Combination Switch**	**1966**	**Motor Switch**
2139	**Ignition Coil**		

Delco Starting and Lighting Installation on the Davis, Model 6-J

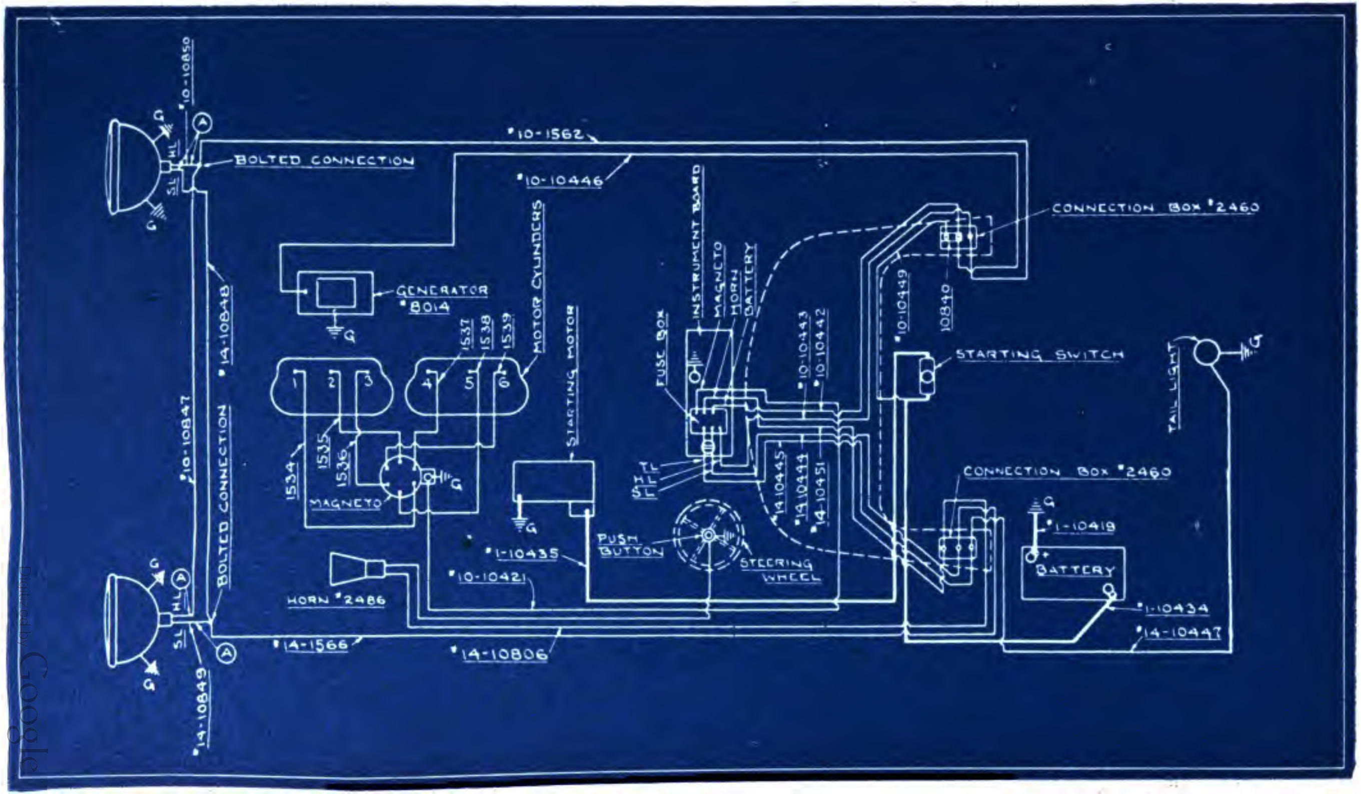


PLATE 20A—WESTINGHOUSE WIRING DIAGRAM FOR CHANDLER 1920

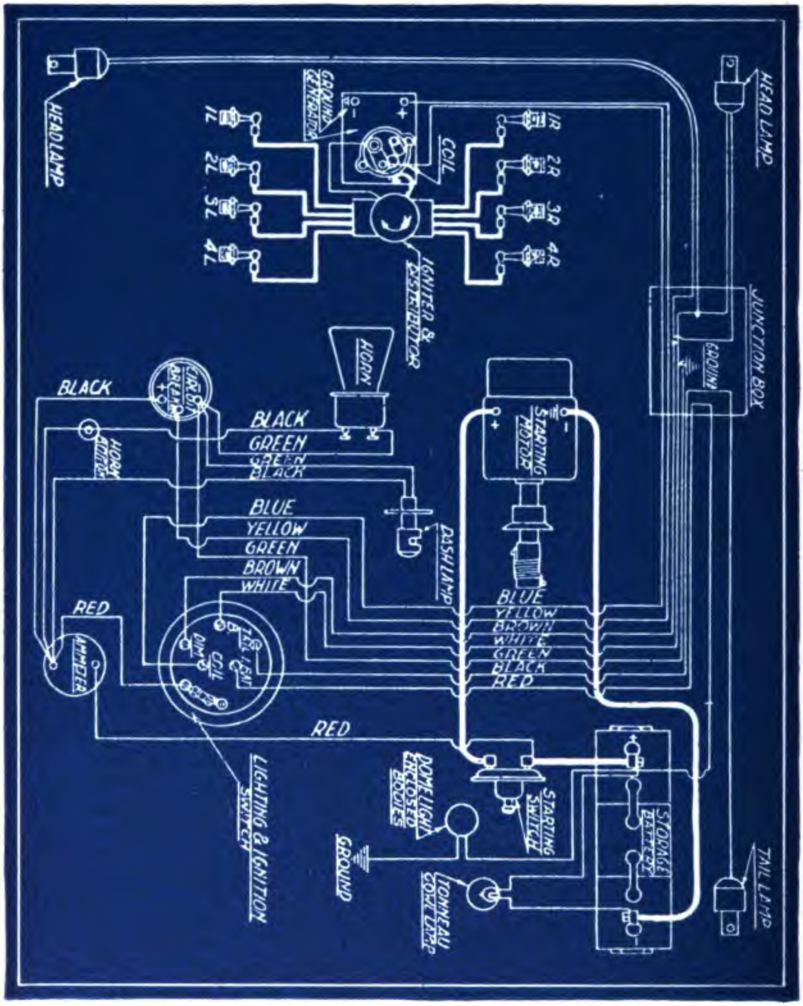


PLATE 21—AUTO-LITE WIRING DIAGRAM FOR CHEVROLET, MODEL D CARS

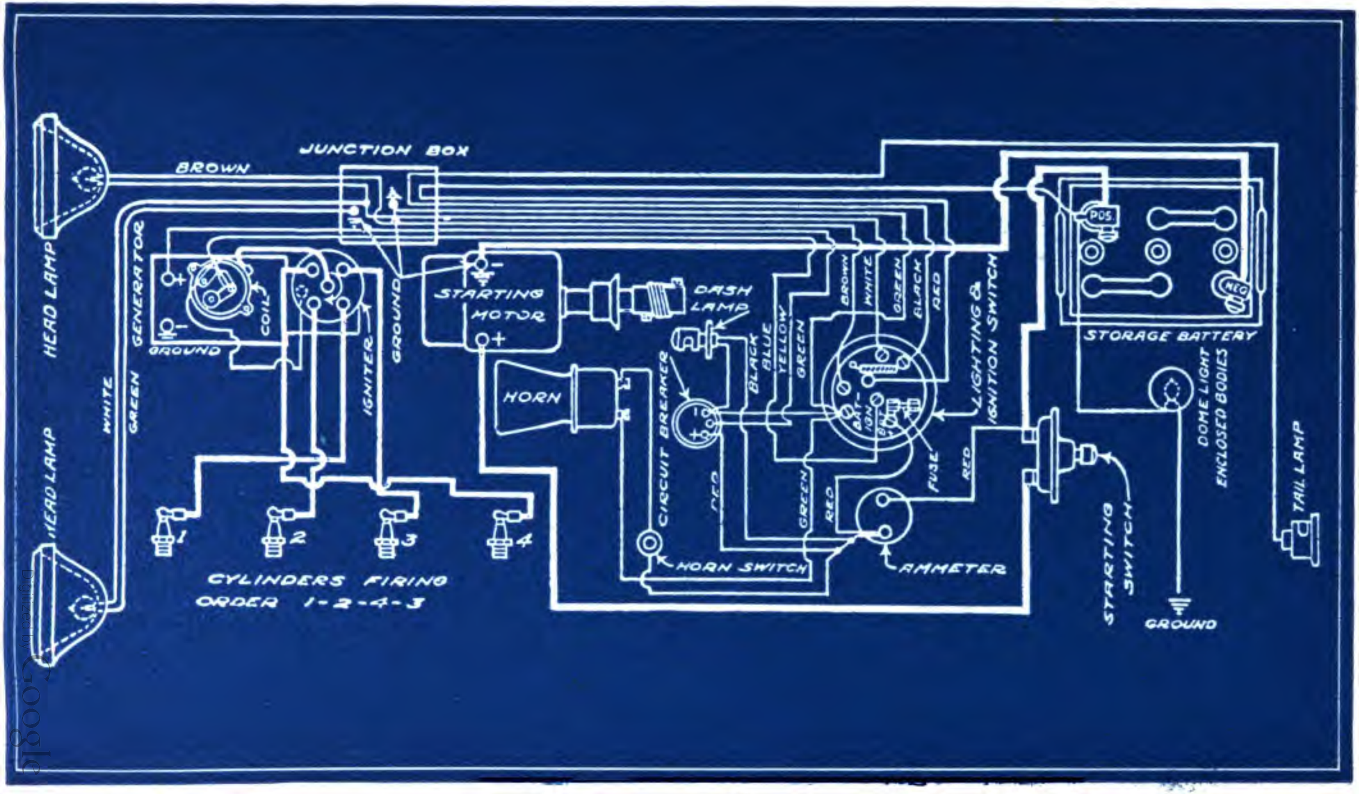


PLATE 22—AUTO-LITE WIRING DIAGRAM FOR CHEVROLET CARS, MODEL "F-A"

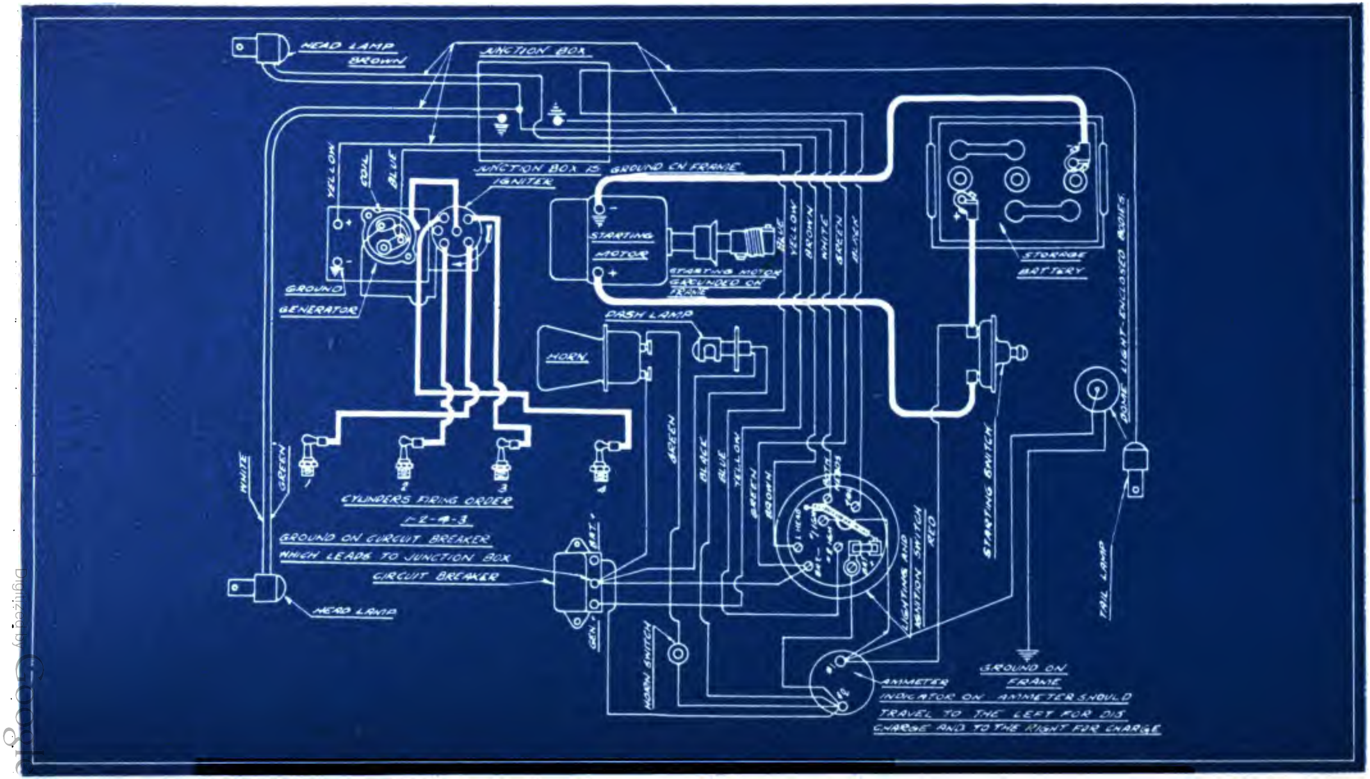


PLATE 28—REMY IGNITION AND AUTO-LITE STARTING AND LIGHTING, CHEVROLET MODEL F-B, 1920

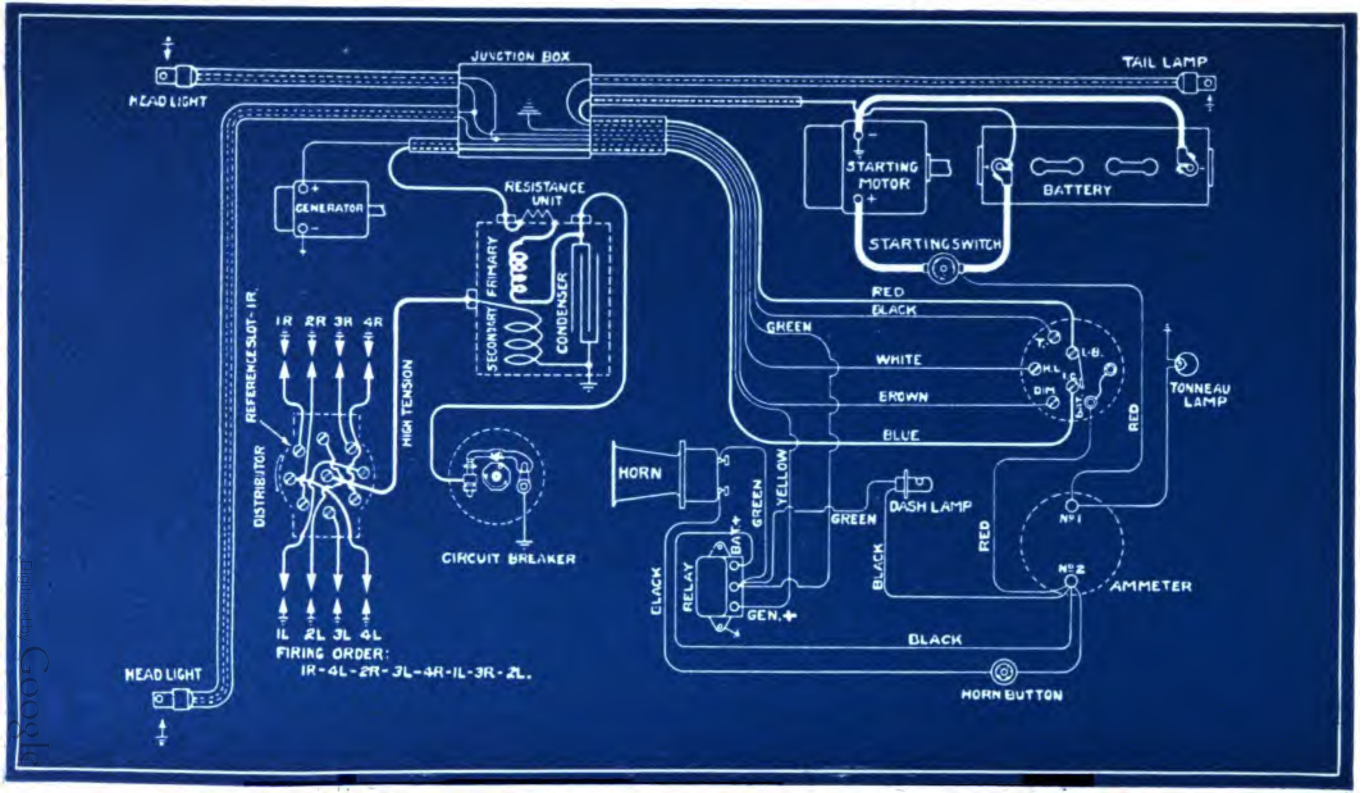


PLATE 24—REMY WIRING DIAGRAM FOR CHEVROLET 1918 CARS, MODELS D-4 AND D-5

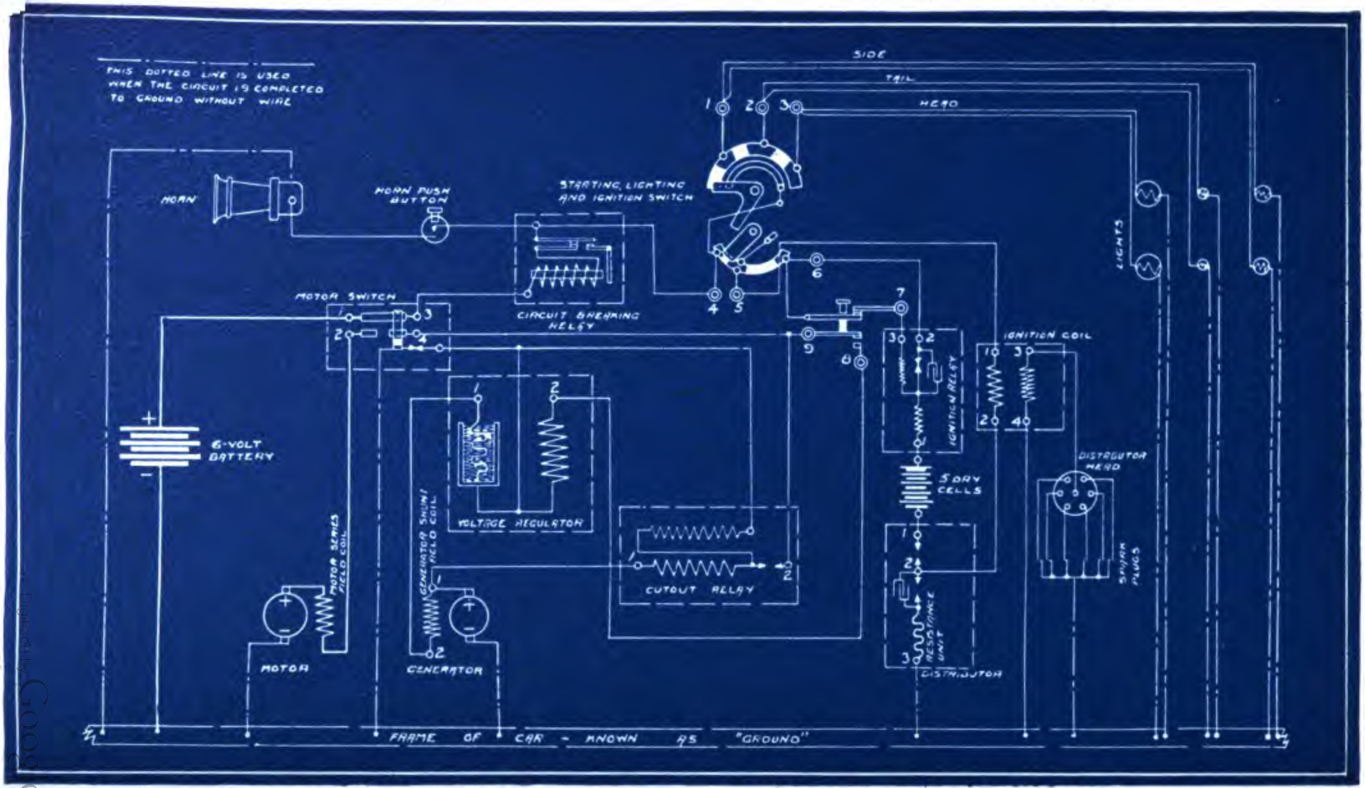


PLATE 25—DELCO CIRCUIT DIAGRAM FOR COLE 1914 FOUR- AND SIX-CYLINDER CARS

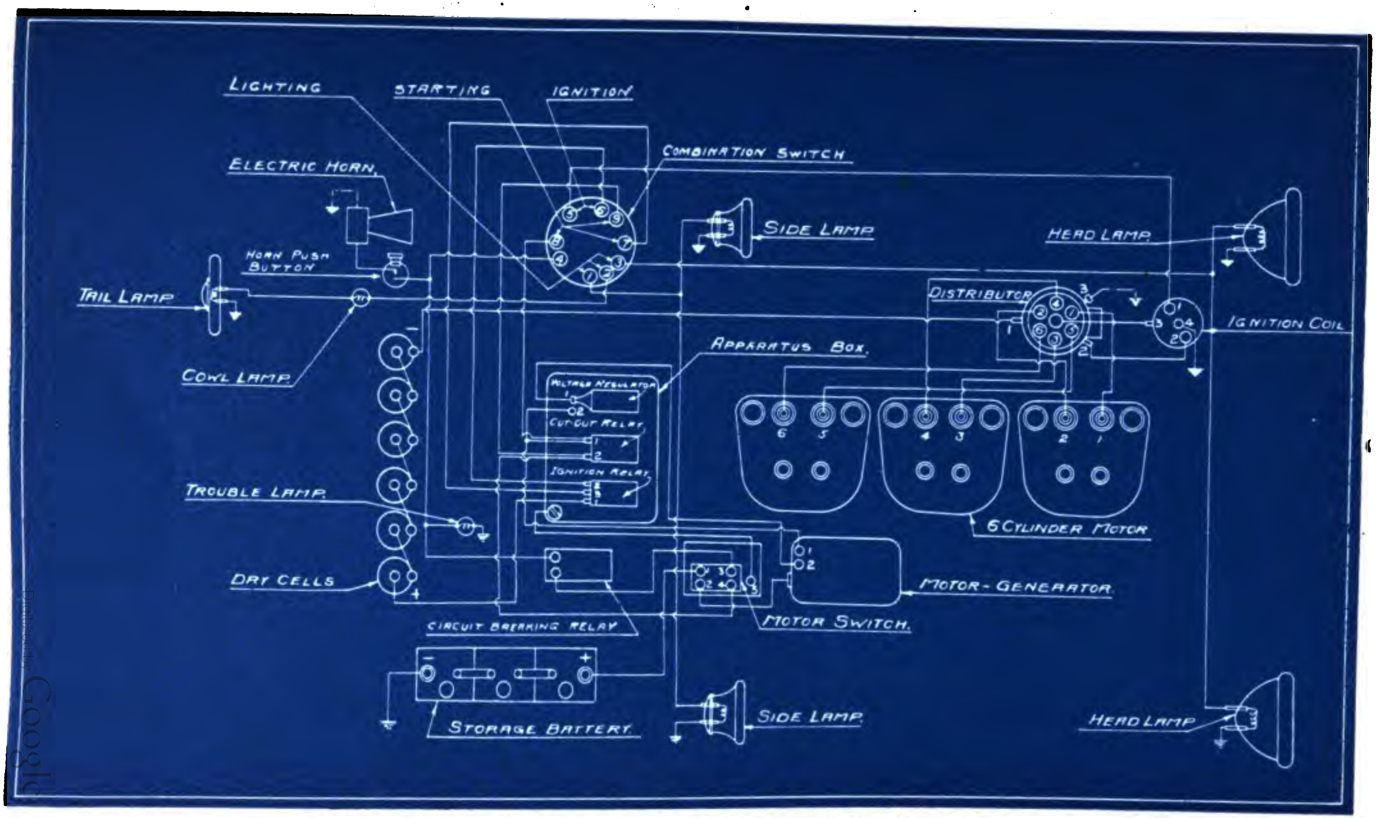


PLATE 26—DELCO WIRING DIAGRAM FOR COLE 1914 FOUR-CYLINDER CARS

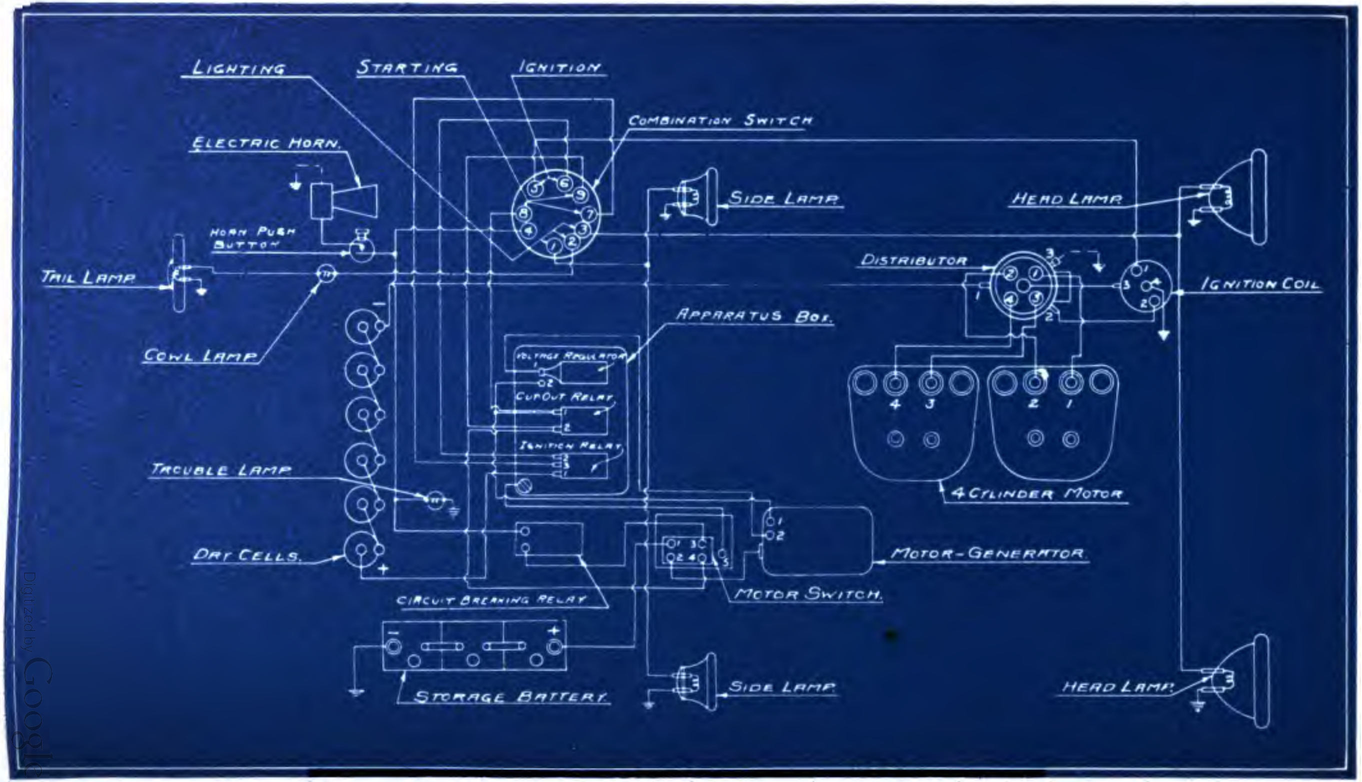


PLATE 27—DELCO WIRING DIAGRAM FOR COLE 1914 SIX-CYLINDER CARS

Protective Devices. *Battery Cut-Out.* In connection with Delco systems using the voltage regulator of the mercury type already described, a battery cut-out or a *cut-out relay*, as it is sometimes termed, is employed. Fig. 242 shows this cut-out together with a diagram of its windings. It consists essentially of a compound-wound electromagnet and a set of contacts designed to be closed by the movement of the pivoted armature of the magnet, and to be opened by a spring when the magnet is not excited. The compound winding consists of a voltage coil of a great many turns of fine wire, as shown at the left of the wiring diagram, and a current coil of a comparatively few turns of heavier wire. As soon as the engine begins to drive the generator the voltage of the latter "builds up" and when it reaches a value between $6\frac{1}{2}$ and $7\frac{3}{4}$ volts, the current passes through the voltage winding of the electromagnet and produces sufficient magnetism to overcome the tension of the spring *B*, attracting the armature *C* to the core *D* which closes the contacts at *A*. These contacts close the circuit between the generator and the storage battery and the whole output of the generator then flows

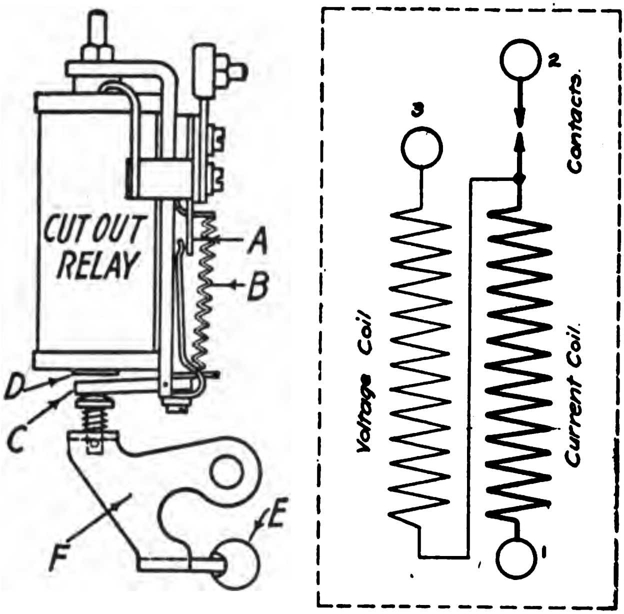


Fig. 242. Sketch and Diagram for Delco Cut-Out Relay

through the current coil, greatly increasing the magnetism in the core in the same direction thus strengthening the pull on the armature C and holding the contacts tightly closed. When the generator slows down and the voltage drops below that of the battery, current flows from the latter to the generator through the current coil in the reverse direction. But, as the voltage coil is directly in circuit with the generator, the flow of current through it continues in the same direction, so that the magnetizing effect of the battery current through the current coil opposes that produced by the voltage coil and the latter is not sufficient to hold the armature against the spring. This causes the contacts to open and prevents any further flow from the battery through the generator. The relay is designed to cut out the battery before the discharge current reaches a value of 1 ampere. As mentioned previously, but few cars subsequent to 1914 are fitted with systems using the mercury voltage regulator and only these systems are equipped with a battery cut-out.

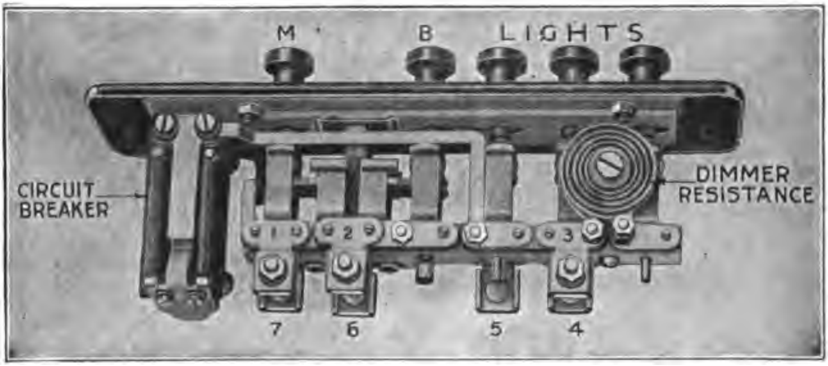
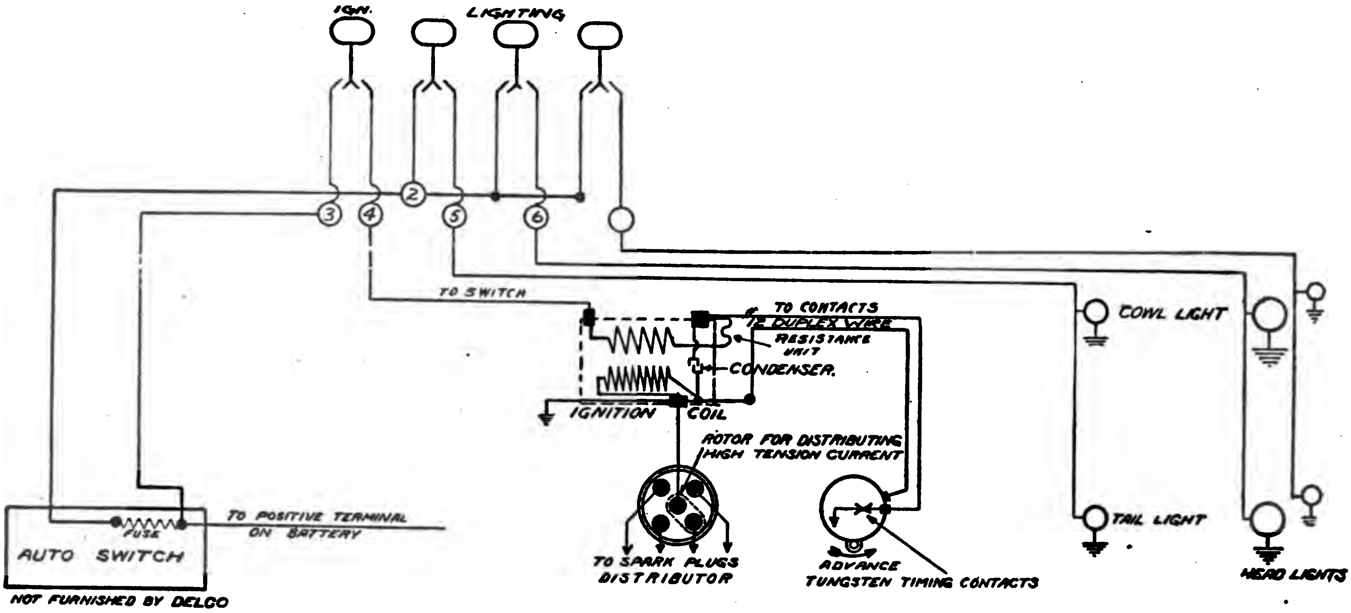


Fig. 243. Delco Combination Switch
Courtesy of Dayton Electrical Engineering Laboratories Company, Dayton, Ohio

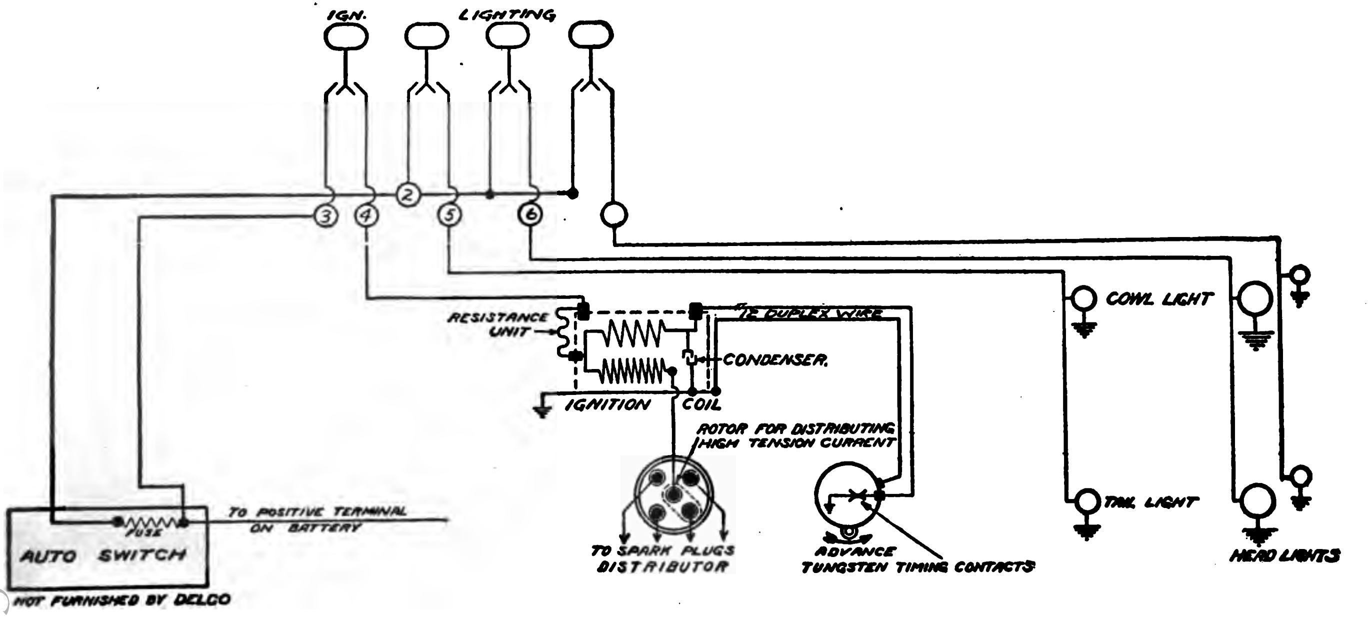
Circuit Breaker. Delco systems fitted to cars subsequent to 1914 are protected by a circuit breaker. This takes the place of the fuse block and fuses employed in most other systems. It is mounted on the combination switch controlling the ignition, generator, and lights, as shown by Fig. 243. The button M controls the magneto ignition circuit, and the button B the dry-battery circuit for the same purpose. In addition both these buttons control the circuit between the battery and the generator for the purpose of



5148 **Distributor** **2138** **Ignition Coil** **1073** **Combination Switch**

Note.—Six cylinder distributor is used.

Delco Starting and Lighting Installation on the Elgin, Model 6-E-16



5141 Distributor **2118 Coil** **1094 Combination Switch**

Delco Starting and Lighting Installation on the Elkhart, 1917 Model *motorizing* the latter to start. When the circuit is closed by either button *M* or button *B*, current flows from the battery to the generator, when the engine is not running and when it is running at speeds below 300 r.p.m., but the amount of current flowing at the lowest engine speeds possible is so small as to be negligible. With the engine stopped, pulling out the button *M* sends sufficient current through the generator armature to run it slowly as a motor so that the gears may be meshed for starting. The amount of current thus employed is limited by a resistance unit in series with the shunt field of the generator.

In principle the circuit breaker is the same as an ordinary electric bell or buzzer, but its winding and the spring controlling its armature are such that it comes into action only when a heavy current passes through it. It is included in every circuit of the electrical system, including the ignition, with the exception of the starting-motor circuit, so that all the current used for every purpose except starting passes through it. But as long as the lamps, ignition, and horn are consuming the normal amount of current, it is not affected. In case any of the wires of these circuits becomes grounded, however, a heavy current passes through the circuit breaker, thus producing a strong magnetic pull which attracts the armature and breaks the circuit. This cuts off the flow of current and the spring again closes the contacts, causing the circuit breaker to pass an intermittent current by vibrating its armature. A current of 25 amperes is required to operate the circuit breaker, but once started it will continue to vibrate on a current as low as 3 to 5 amperes.

Wiring Diagrams. The Delco system is applied to such a number of different makes of cars, frequently varying in detail not only with each succeeding year's models of the same make, but also on different models of the same make and same year of production, that space would not permit of reproducing them all here. While these wiring diagrams differ in detail, they may, however, be divided into three general classes based upon the type of regulation used with the generator. At least one of each of these classes of wiring diagrams is reproduced here and familiarity with them will make it easy to trace the wiring of any system of this make.

Cadillac. Wiring diagram of the 1912 model is given in Fig. 244. Reference to a model as early as this is made to show the pro-

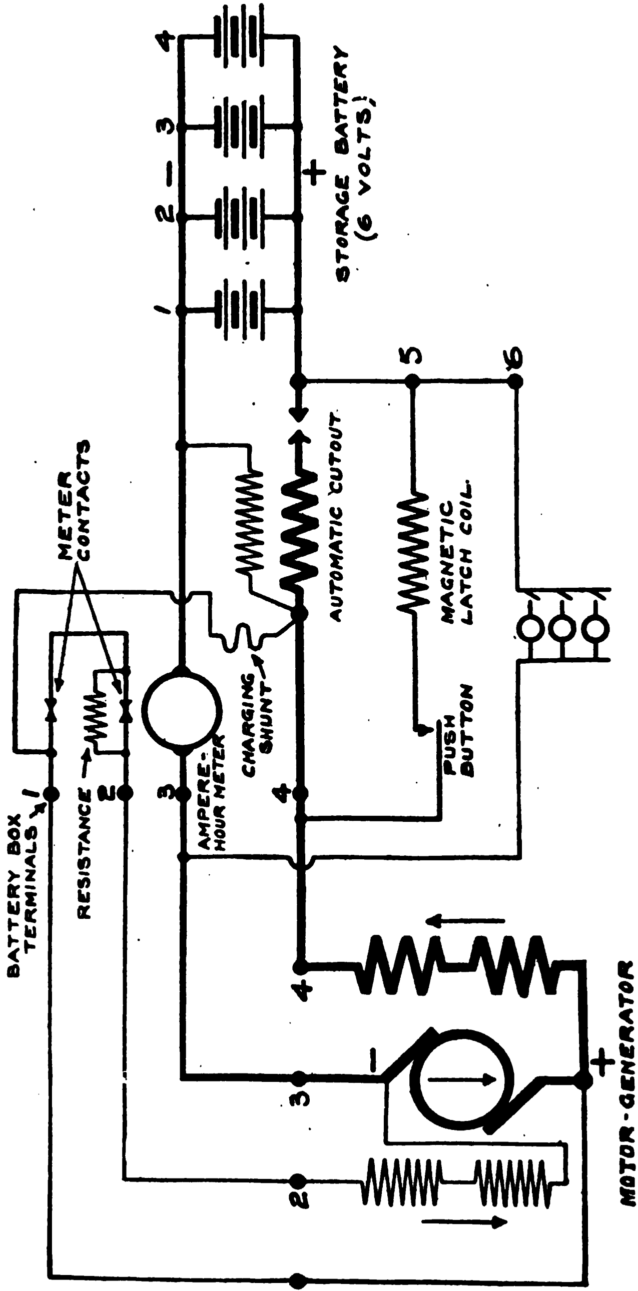


Fig. 244. Wiring Diagram for Generator Circuits of Delco Installation on Cadillac 1912 Model

gressive steps represented by each succeeding year; also because there are a great many of these cars still in use. Twelve cells of battery were employed though the dynamo generated current at 7 to 8 volts (nominally a 6-volt system), and as shown by the diagram which illustrates the connections of the generator circuit, the battery was divided into four groups of three cells each in series-multiple for charging. An ampere-hour meter showed the state of charge of the battery and also indicated how much current was consumed by the various circuits, including the starting motor. Regulation was by means of extra resistance inserted in the field circuit of the generator and an automatic battery cut-out was employed. The diagram shown in Fig. 244 is applicable to the connections of all the Delco 6—24-volt systems in use, when the machine is operating as a generator. The heavy lines indicate the main charging circuit. Fig. 245 shows the starting motor circuit of all the Delco 6—24-volt systems, and it will be noted that the cells of the battery are all in series to supply current at 24 volts, group No. 4 being utilized to supply current to the lamps at 6 volts.

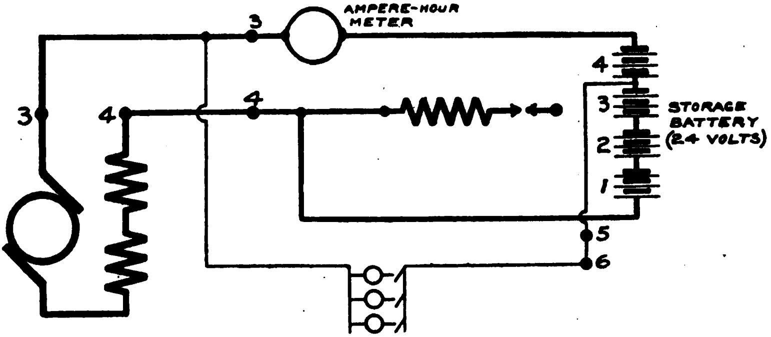


Fig. 245. Wiring Diagram of Starting Motor Circuit for All Delco 6—24-Volt Systems

Fig. 246 shows the wiring diagram of the Cadillac 1914 model. This is a straight 6-volt system, the generator being provided with the mercury type of voltage regulator previously described and an automatic battery cut-out. The starting-motor circuit is controlled by an external switch and the lighting circuits are protected by fuses. The earlier form of the combination switch controlling the ignition and the preliminary motorizing of the generator for starting, is seen at the right. The 1914 diagram is essentially the same, the chief

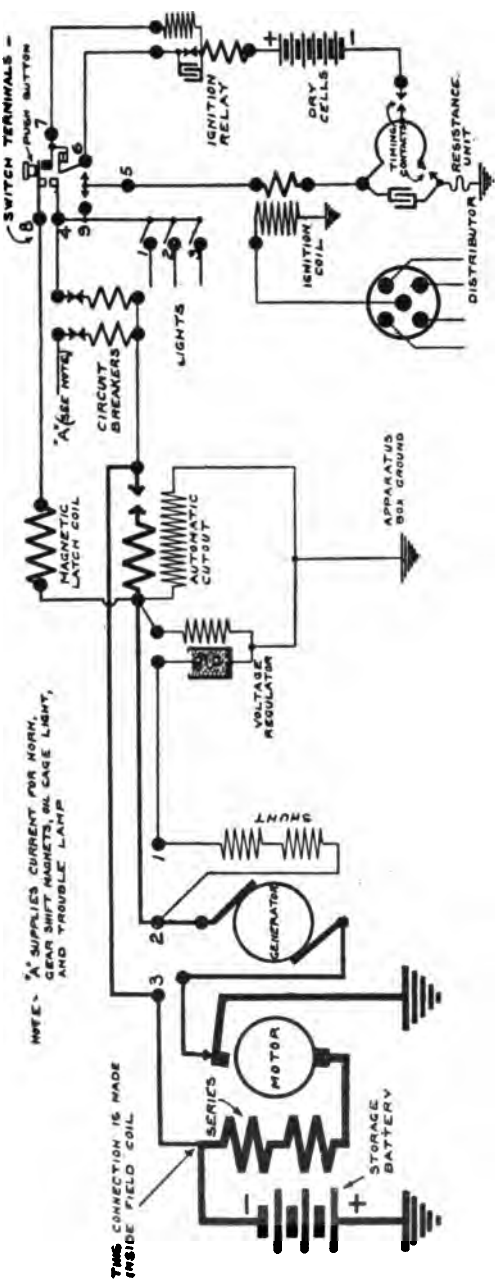


Fig. 246. Wiring Diagram for Delco System on Cadillac 1914 Models

difference being the substitution of the motor brush switch for the external switch controlling the starting motor. The fuses were also replaced by two circuit breakers, one for the main lighting circuits and ignition, and the other for the auxiliary lamps, horn, and the gear-changing solenoids, the model of that year being equipped with an electric magnetic gear shift in the transmission.

In the 1915 wiring diagram, Fig. 247, the method of regulating the generator has been changed to the mechanically varied resistance already described. One circuit breaker protects all fuses and a rotary form of combination switch controls all the circuits.

Buick. Two different types are employed on the 1915 models, the only distinction, however, being in the method of

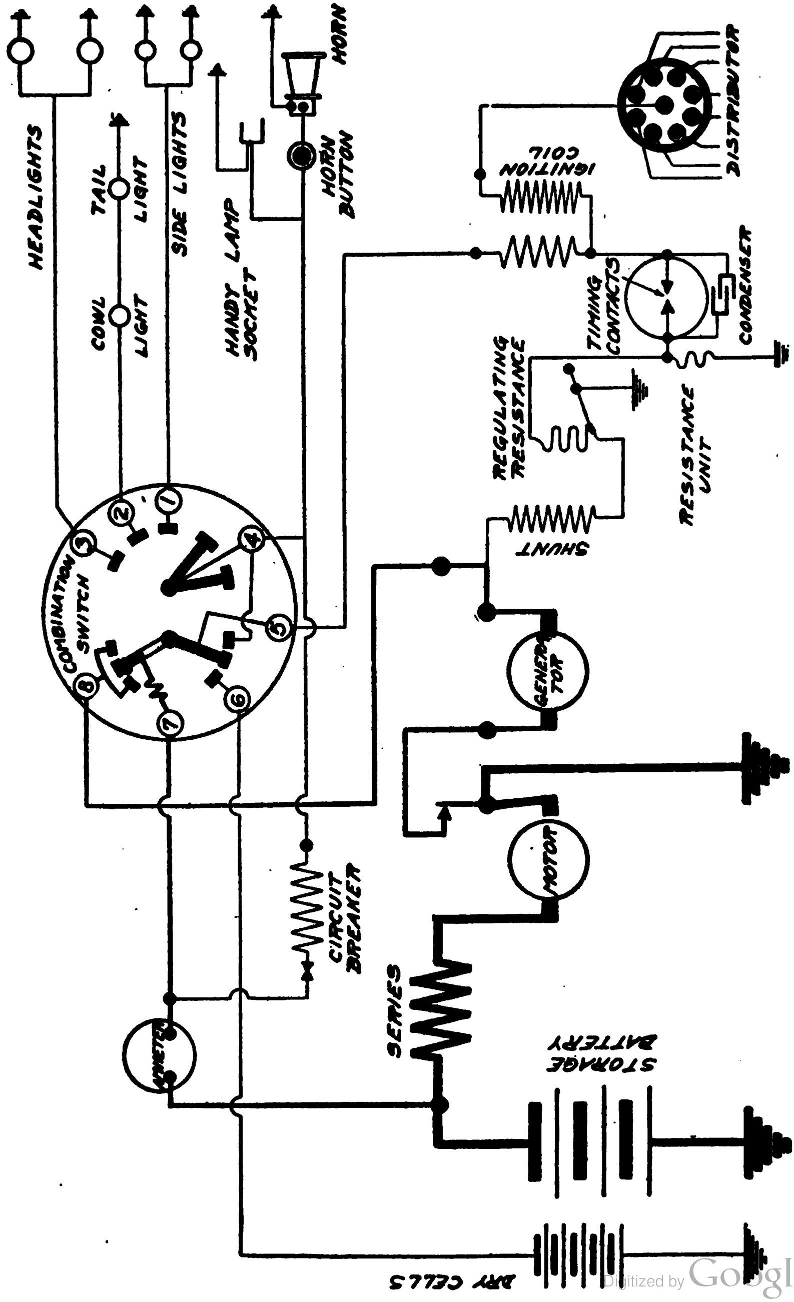


Fig. 247. Wiring Diagram for Delco System on Cadillac 1915 Models

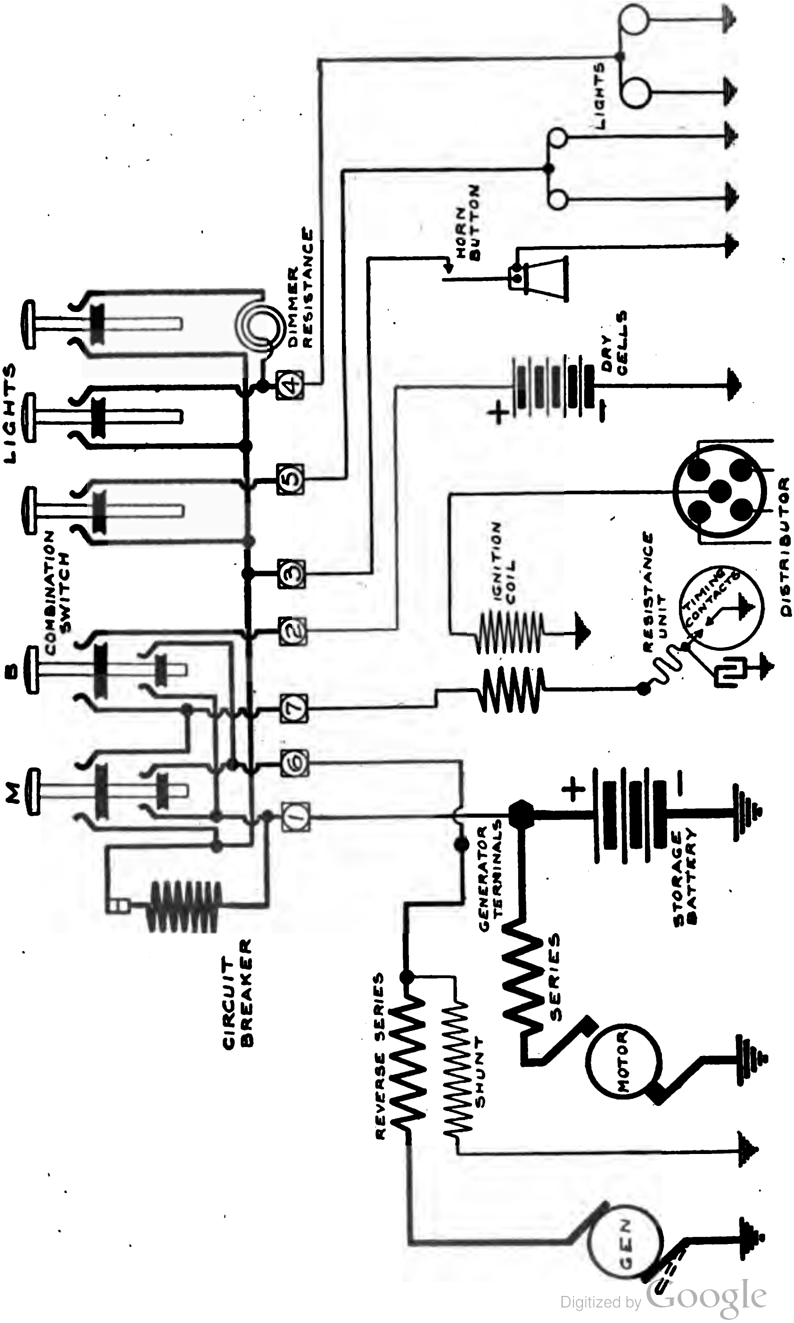


Fig. 248. Wiring Diagram for Delco Installation on the Buick Models C24 and C25

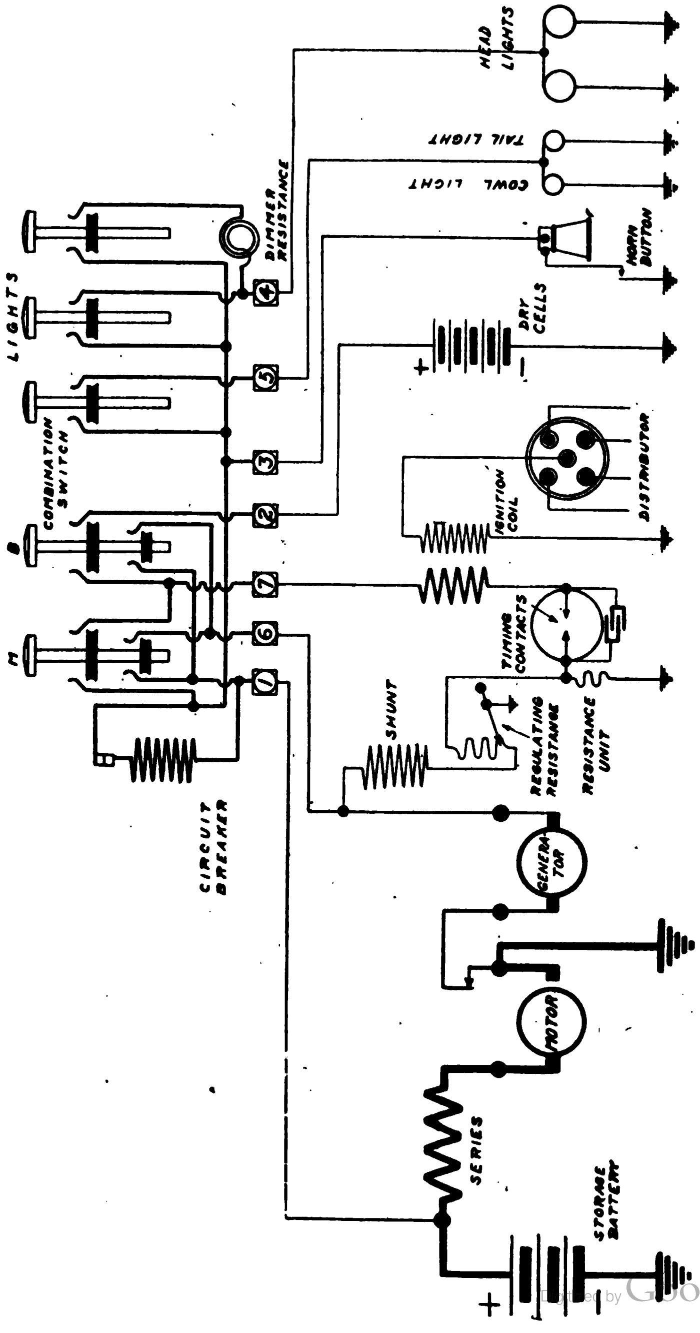


Fig. 249. Wiring Diagram for Delco Installation on Buick Models C36 and C37

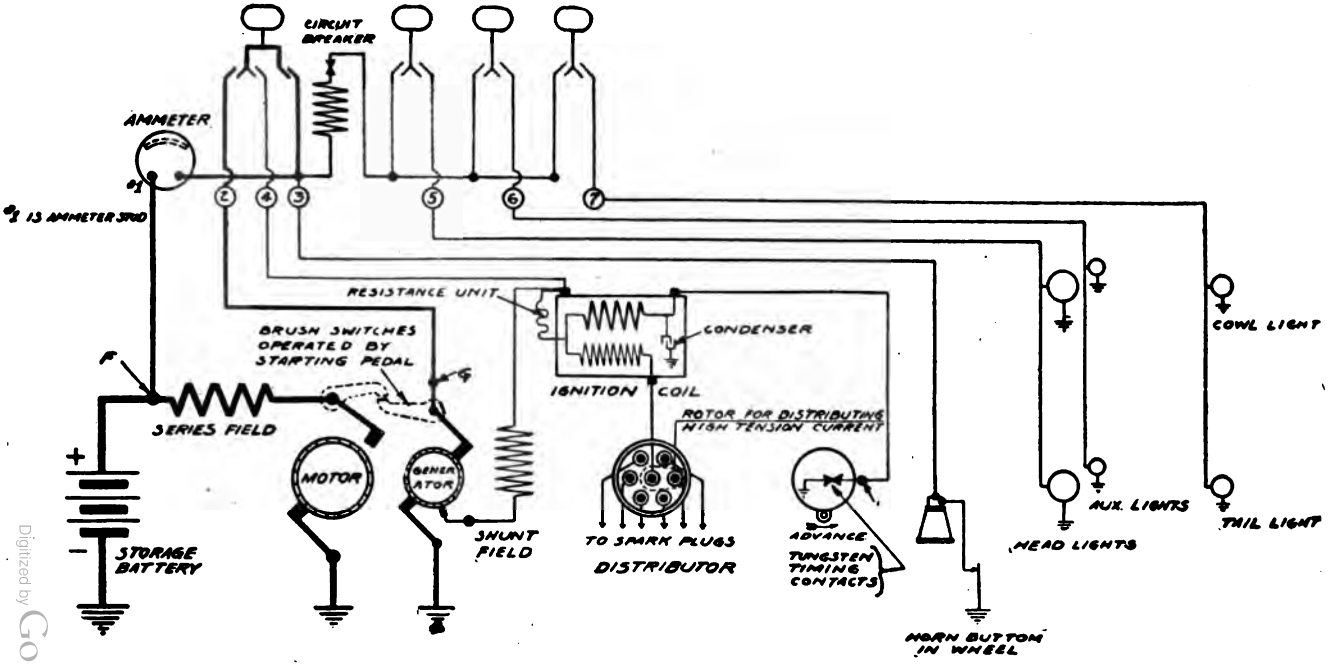
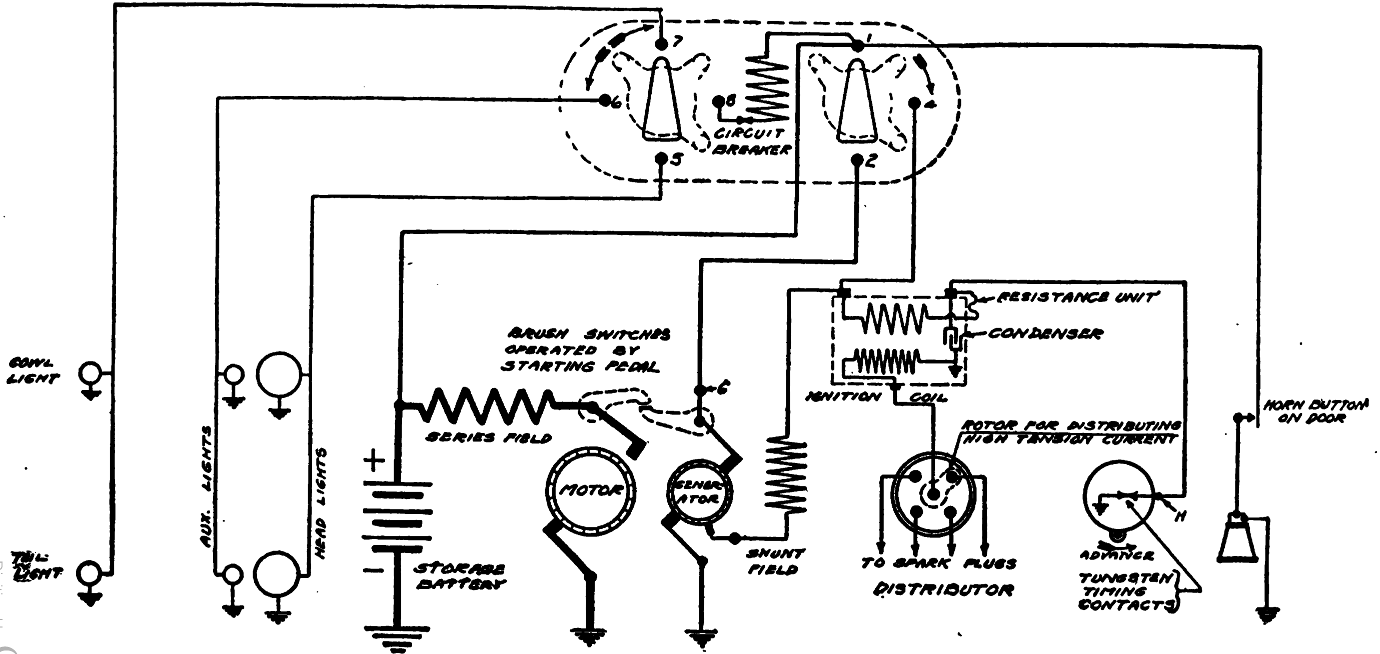


Fig. 250. Wiring Diagram for Delco Installations on Buick 1916 Models

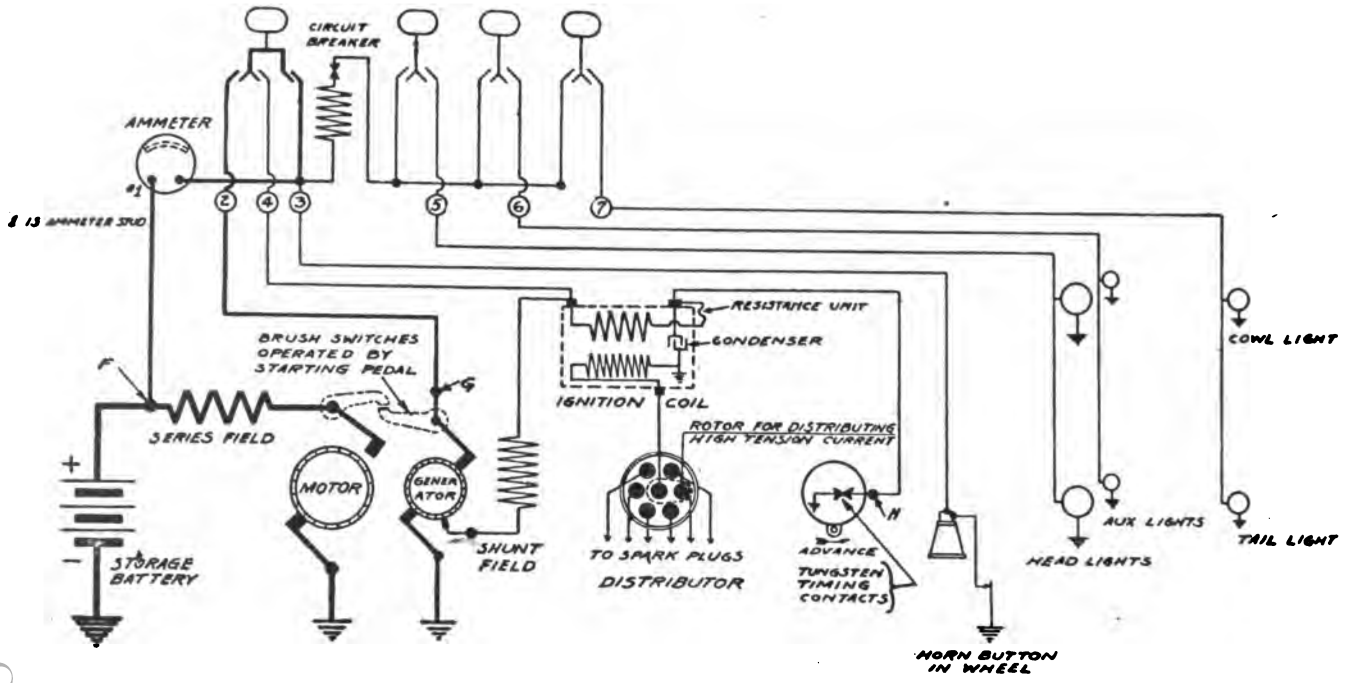


94 or 115 **Motor Generator**

2138 **Ignition Coil**

1075 **Combination Switch**
12647 **Motor Clutch**

Delco Starting and Lighting Installation on the Buick, Models D-34-35



70 Motor Generator
12224 Motor Clutch

2138 Ignition Coil
1066 Combination Switch

Delco Starting and Lighting Installation on the Buick, Models D-44-45-46-47 generator regulation. That of Models C24 and C25 is by means of the reversed series-field winding or bucking coil, while that of Models C36 and C37 utilizes the mechanically varied resistance or rheostat operated by a centrifugal governor, as shown in Fig. 249. The buttons *M* and *B*, in each instance, control the ignition circuit, depending upon whether the storage or the dry battery is called upon for the ignition current as well as for the current to motorize the generator preliminary to starting. The remaining three buttons of the combination switch control the lights and dimming resistance and it will be noted that the circuit-breaker forms a part of every one of the circuits except that of the starting motor.

On the 1916 Buick models, the generator is regulated by the third-brush method; the brush switches are operated by the starting pedal; only the lighting circuits are protected by the circuit-breaker, and an ammeter is inserted in the circuit with the latter, Fig. 250. No mention is made of the details of any of the ignition circuits in these diagrams as that is taken up in the section on Ignition. Apart from the fact that the Oakland Model 50 has a 4-pole motor winding instead of the bipolar type shown in all the previous diagrams, the wiring diagrams of the Oakland models for 1916 are the same as those shown for the Buick. On the two 1915 models of the Cole, the distinction between the wiring diagrams is the same as that mentioned for the two classes of Buick models of the same year, i.e., one having the reversed series field, and the other the variable resistance controlled by the governor—the combination switch, circuit-breaker, and other connections of the diagrams being essentially the same.

Six-Volt; Two-Unit; Single-Wire

Generator. This generator is a bipolar machine of the shunt-wound type, a section of which is illustrated in Fig. 251. As installed on the Westcott (1917)—a wiring diagram of this installation being illustrated in Fig. 255—the generator is driven from the water-pump shaft through a one-way clutch, that is, a type that will drive when turned in one direction but will run free when driven in the opposite direction. This permits the generator armature to revolve when the engine is not running, thus preventing a heavy current discharging through the generator from the battery when the ignition switch is turned on while the engine is idle. This is due to the fact that the same switch which closes the ignition circuit puts the generator in circuit, as explained in connection with the wiring diagram. If the generator armature could not revolve, its resistance would be very low, so that a heavy discharge would take place, but as it is permitted to become *motorized,* its armature builds up a strong counter e.m.f., as explained under Electric-Motor Principles, Part I, thus greatly increasing the resistance and greatly decreasing the amount of current that will pass through it.

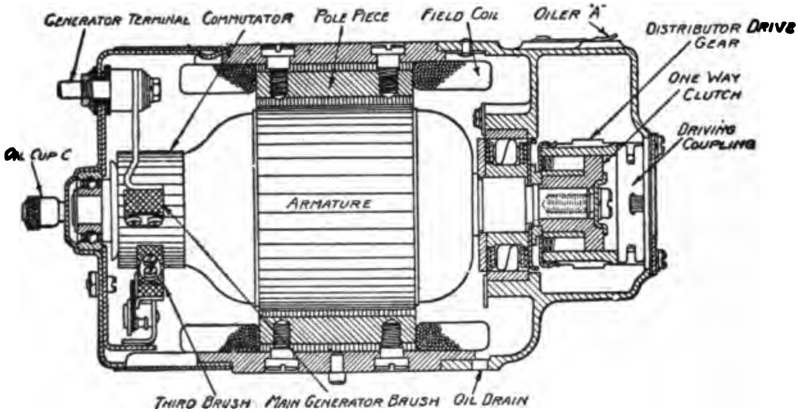


Fig. 251. Generator of Delco Two-Unit System
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

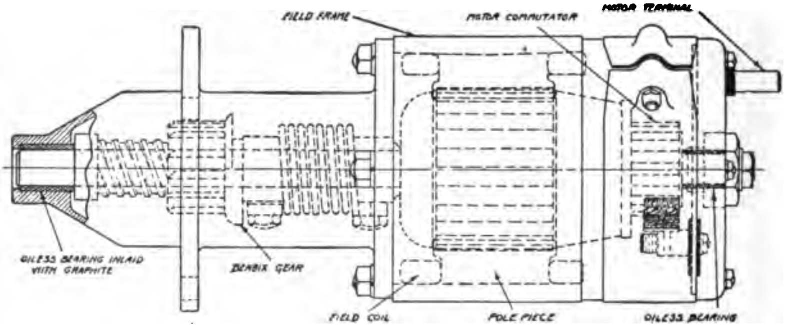
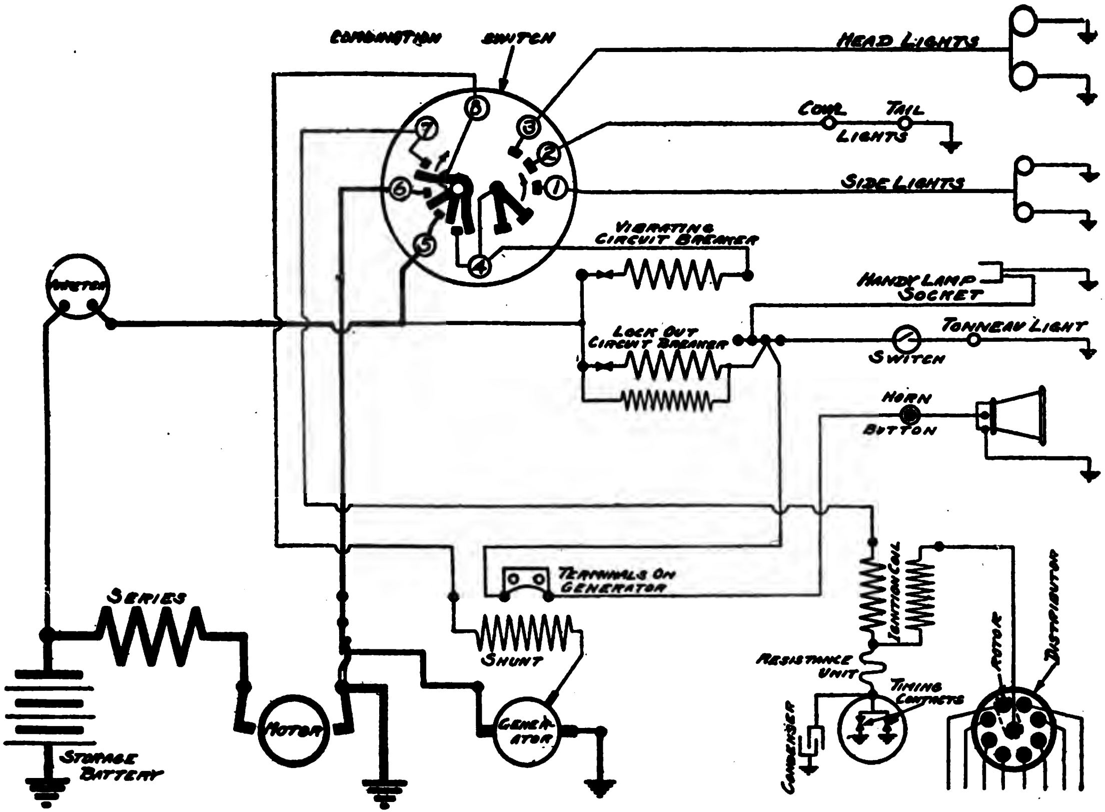


Fig. 252. Diagram of Starting Motor for Delco Two-Unit System

Regulation. The regulation is of the third-brush type, which has already been explained in detail in connection with the single-unit Delco system.

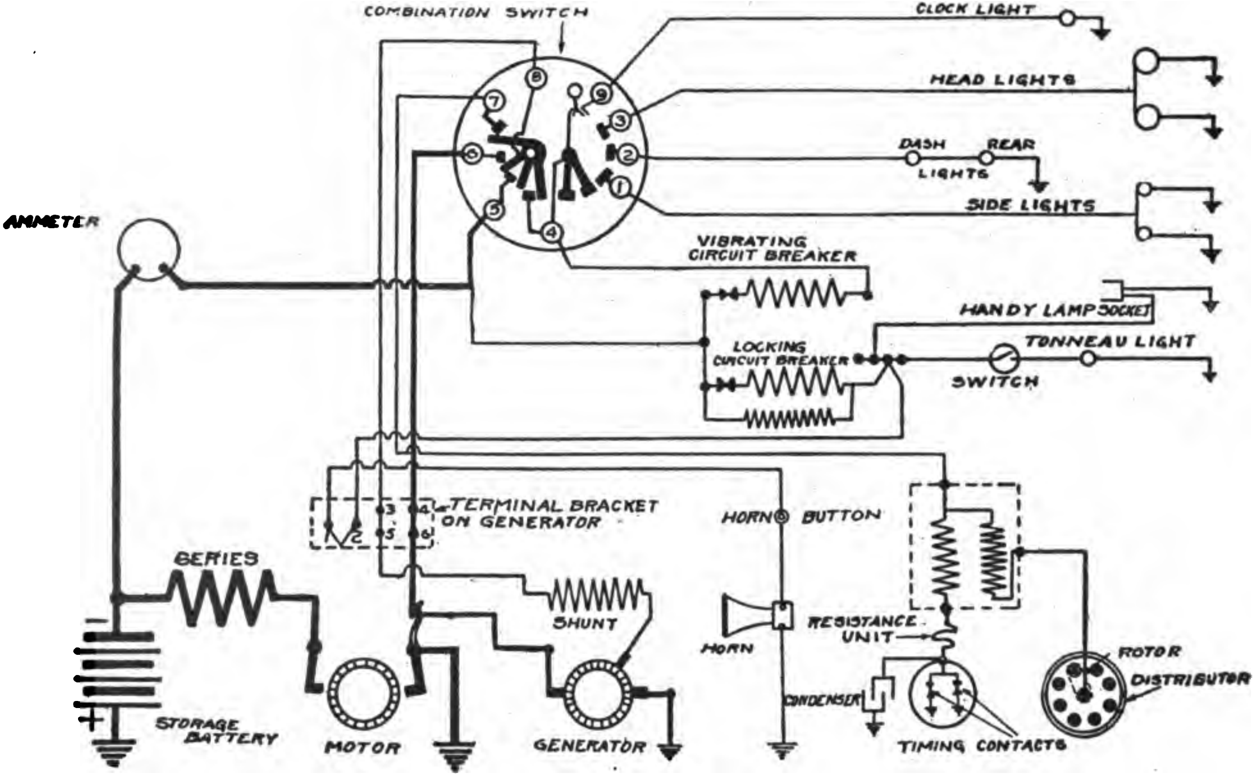
Starting Motor. Fig. 252 shows a longitudinal view of the starting motor fitted with the Bendix drive, while an end view of the motor,



Motor Generator No. 78
Ignition Coil No. 2115

Combination Switch No. 1062 or 1069

Delco Starting and Lighting Installation on the Cadillac, Model 53



98	**Motor Generator**	1077	**Combination Switch**	5311	**Horn**
5150	**Distributor**	5705	**Circuit Breaker**	1061	**Horn Switch**
2115	**Ignition Coil**			12677	**Motor Clutch**

Delco Starting and Lighting Installation on the Cadillac, Model 55 illustrating the commutator and brushes, is shown in Fig. 253. This motor is of the multipolar type, and its method of control differs from the single-unit type in not employing the brush switch.

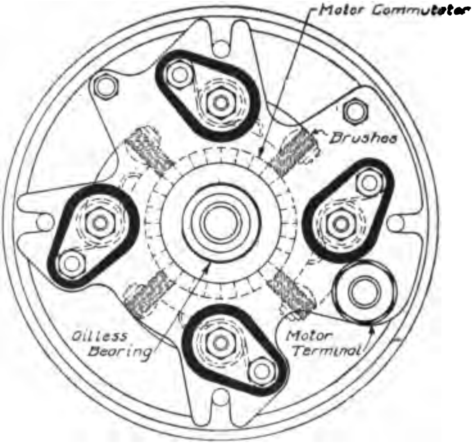


Fig. 253. End View of Delco Starting Motor, Showing Commutator and Brushes

Starting Switch. A pedal-operated plunger type of switch is employed, for which the advantage is claimed that its contacts are self-cleaning. The method of effecting this will be apparent from the part-sectional view of the switch, Fig. 254. The switch is in barrel form, with the springs incorporated in the plunger, while the stationary and movable contacts are given a contour that causes them to scrape against each other when coming into contact, thus keeping these surfaces bright.

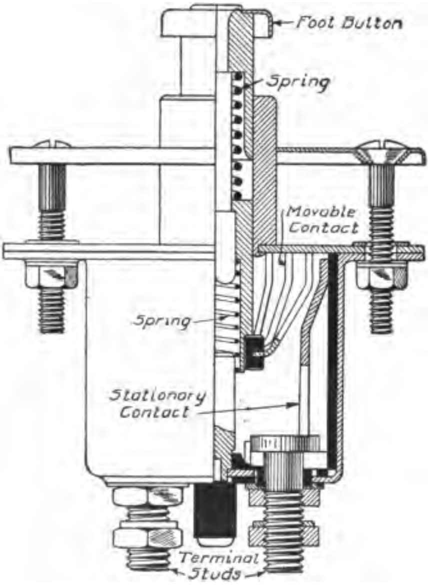


Fig. 254. Part Section of Delco Starting Switch

Wiring Diagram. By comparing this wiring diagram, Fig. 255 with Fig. 250, which shows the single-unit Delco system as installed on a Buick machine, a clearer idea of the difference in the requirements of the single- and two-unit sets, where their circuits are concerned, will be obtained. It will be noted that the connections of the lamps, ignition, and horn are the same, though the method for

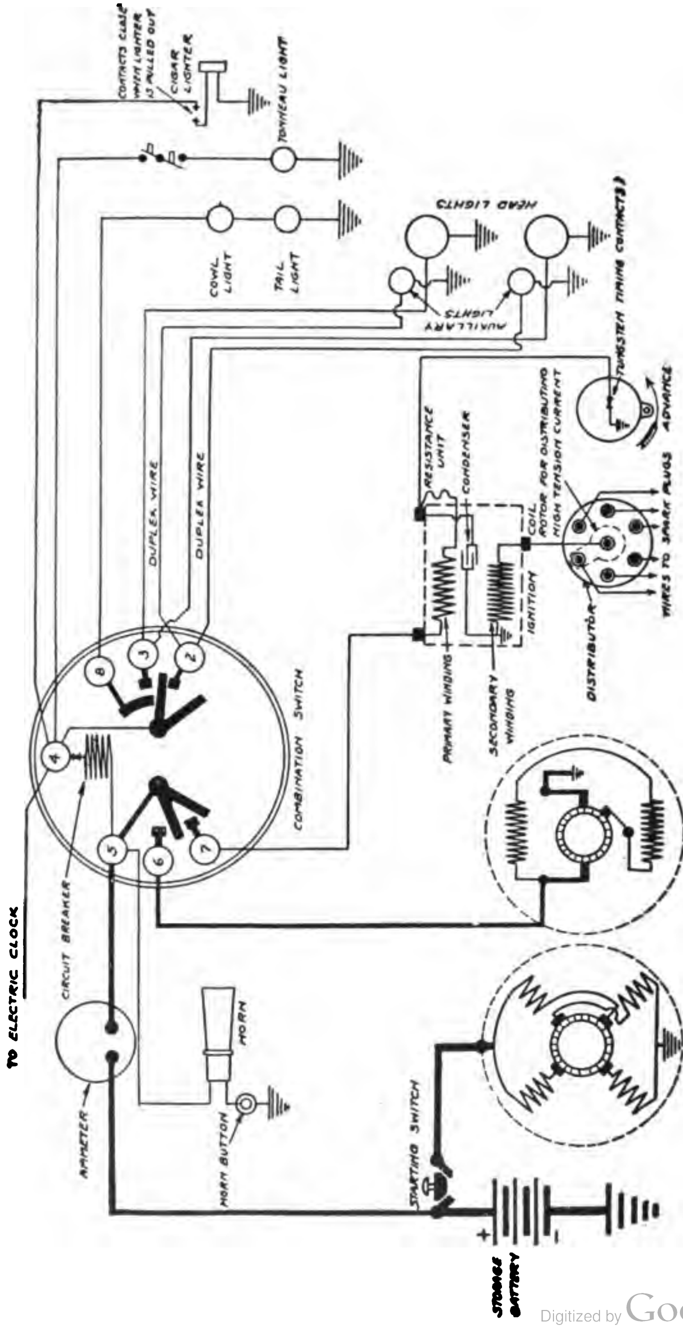


Fig. 255. Complete Wiring Diagram of Delco System on 1917 and 1918 Westcott Cars

controlling them differs. Likewise that all of these, with the exception of the ignition, are protected by the circuit-breaker. The lighting circuits appear more complicated simply because there is an extra light (tonneau light) and two additional accessories, i.e., a connection for an electric cigar lighter and one for an electric clock.

The chief difference is in the generator and the starting-motor circuits. An unusual feature in this essential is a two-part switch member which controls the ignition and the generator circuits. By this method, opening the ignition switch opens the circuit between the storage battery and the generator, so that a battery cut-out is dispensed with. There is, even under the most favorable conditions, a perceptible interval between the closing of the ignition switch and the starting of the engine, and in winter this may be increased to a considerable period, during which there will be a heavy discharge from the battery through the generator, unless means to avoid it be provided. The way this is accomplished is by the employment of a one-way driving clutch on the generator, as already described. When running, the generator is driven by the pump shaft of the engine in one direction; when the battery current passes through it, it is free to run as a motor in the opposite direction, despite the fact that the engine is idle. While operating as a motor, its resistance is sufficiently high to cut this discharge from the battery to negligible proportions. As soon as the engine starts, the generator is driven in the opposite direction, and its voltage immediately overcomes that of the battery, and the battery begins to charge.

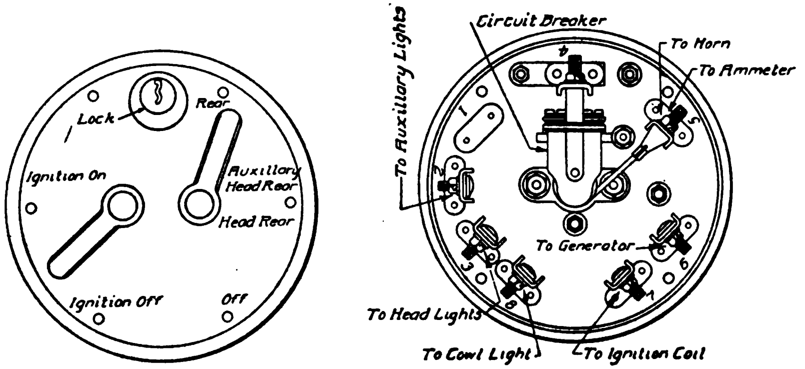
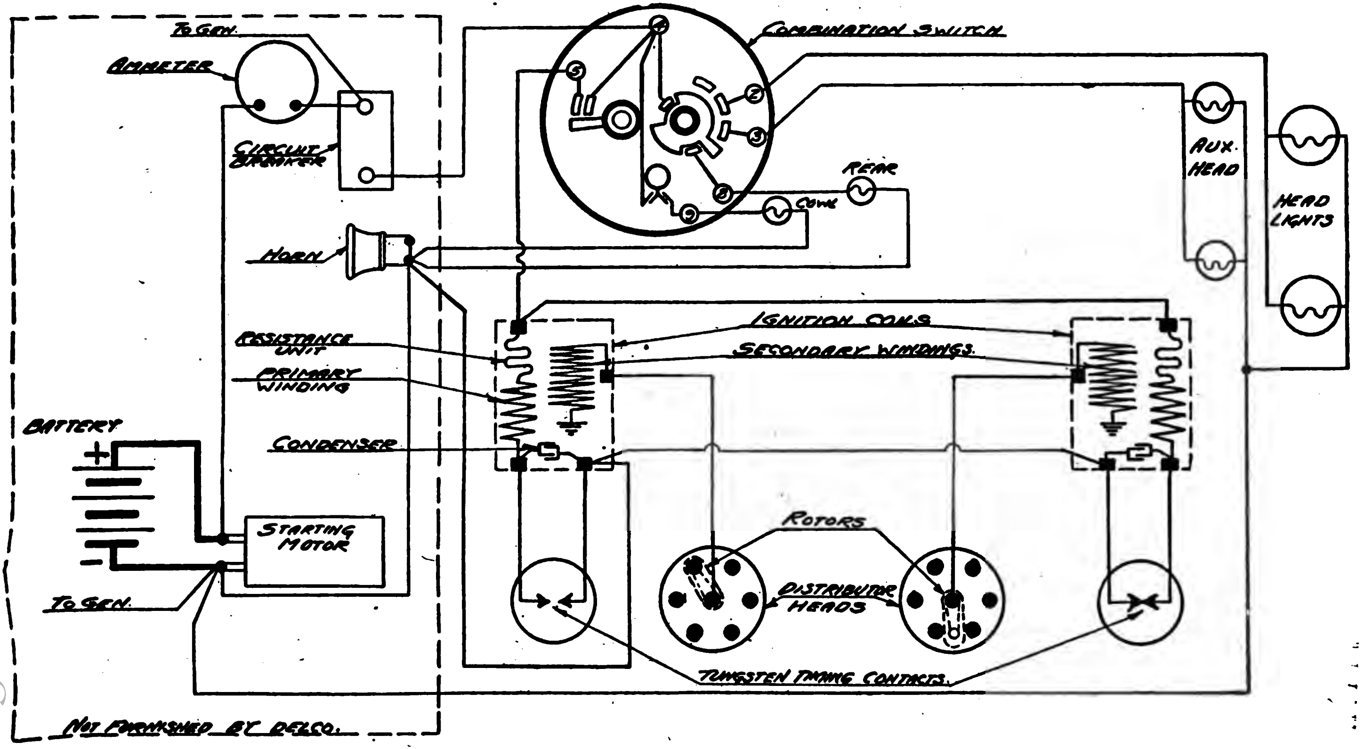


Fig. 256. Front and Reverse Face of Combination Switch for Delco Two-Unit System

The face of the starting switch and the details of the connections on its reverse are shown in Fig. 256.

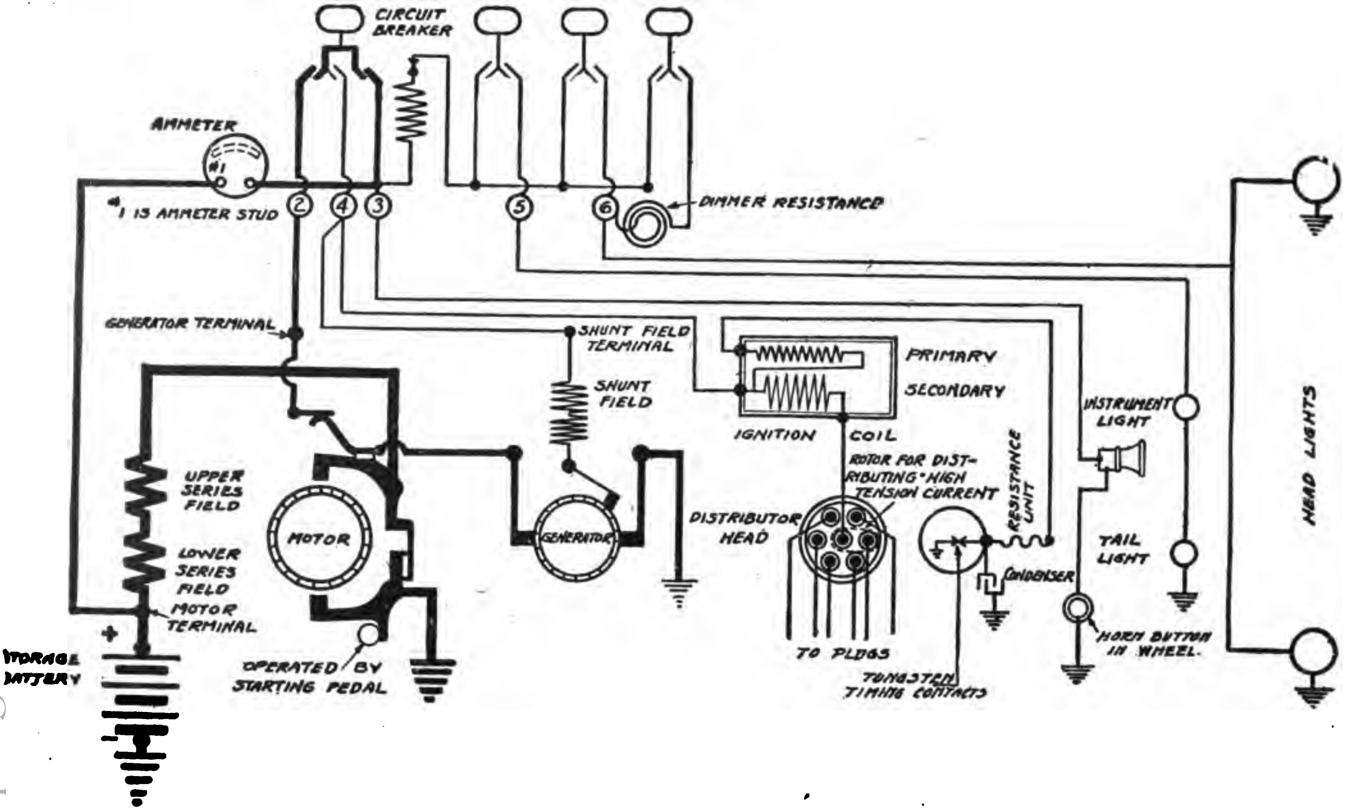
Delco Instructions

General Instructions. If the starter, lights, and horn all fail, the trouble is in the storage battery or in its connections, one of the connections being loose or corroded, or one of the battery jars being broken. When the lights, ignition, and horn all work normally but the starter fails to operate, the trouble is in the motor-generator, or dynamotor, and may be caused by the motor brush switch not dropping on the commutator, or by dirt or grease on the commutator. Owing to the heavy current required by the motor in starting, if the lights are on at the time, they will become dim when the starting circuit is closed but remain so only momentarily. In case they go out or become very dim when the starting-motor circuit is closed, it indicates that the battery is practically depleted. When the motor fires properly on the *M* button of the combination switch, but not on the *B* button, the wiring between the dry cells or the connection from the dry cells to the combination switch must be at fault. When the ignition works all right on button *B*, but not on *M*, the trouble must be in the leads running from the storage battery to the generator, or in the lead running from the small terminal on the generator to the combination switch, or in the battery connections, either of the cells themselves or the ground connections. If the supply of current from both the dry cells and the storage battery is ample, yet both ignition systems fail, trouble should be sought first at the timer contacts, then the coil, resistance unit, and the condenser. An examination of the timer contacts will show whether they are clean, square, and in good working condition; if badly burned and pitted, true them up square with a strip of fine emery cloth or a very fine flat file. The coil, resistance unit, and condenser may be tried out with the test-lamp outfit. If the lamp lights when contact is made through the terminals of the coil or the resistance unit, it indicates that nothing is wrong with them, but if it lights on the condenser it shows that the insulation of the latter has broken down, as there should be no circuit through the condenser. The only remedy is to replace it. All of the units mentioned work in the same capacity for each system of ignition.



5155 Distributor (includes 2—8144 coils) **1083 Combination Switch**

Delco Ignition Installation on the Haynes, Models 40, 40-R, 41



83	**Motor Generator**	1071	**Combination Switch**
5134	**Distributor**	12207	**Motor Clutch**
2127	**Ignition Coil**		

Delco Starting and Lighting Installation on the Hudson, 1917 Super-Six

If, for purposes of making tests, it becomes necessary to remove any of the electrical apparatus from the car, or to make any adjustments, the storage battery should first be disconnected. This can be done most conveniently by removing the ground connection and winding the bare terminal with electrician's tape so that it cannot come in contact with anything that would cause a short-circuit. The car should not be run with the storage battery disconnected from the generator or with the battery off the car unless the generator is short-circuited, as otherwise serious damage may result, as the generator is likely to be burned out.

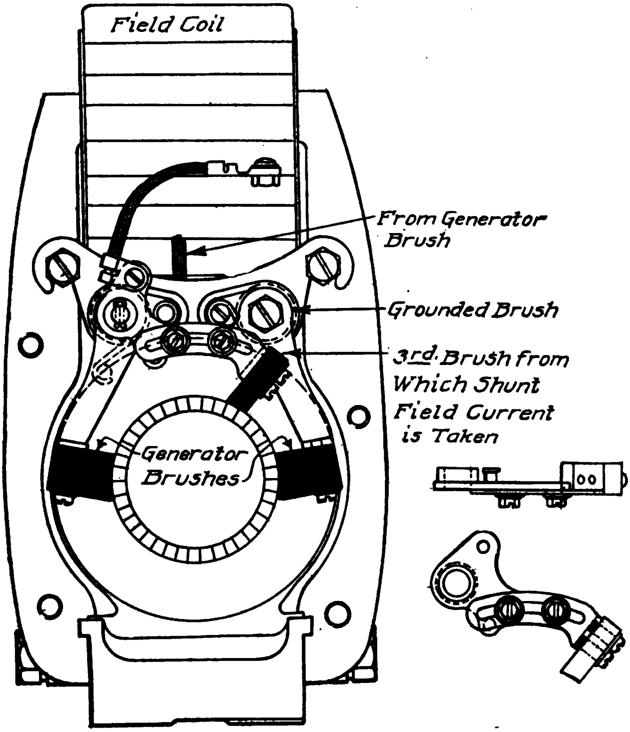
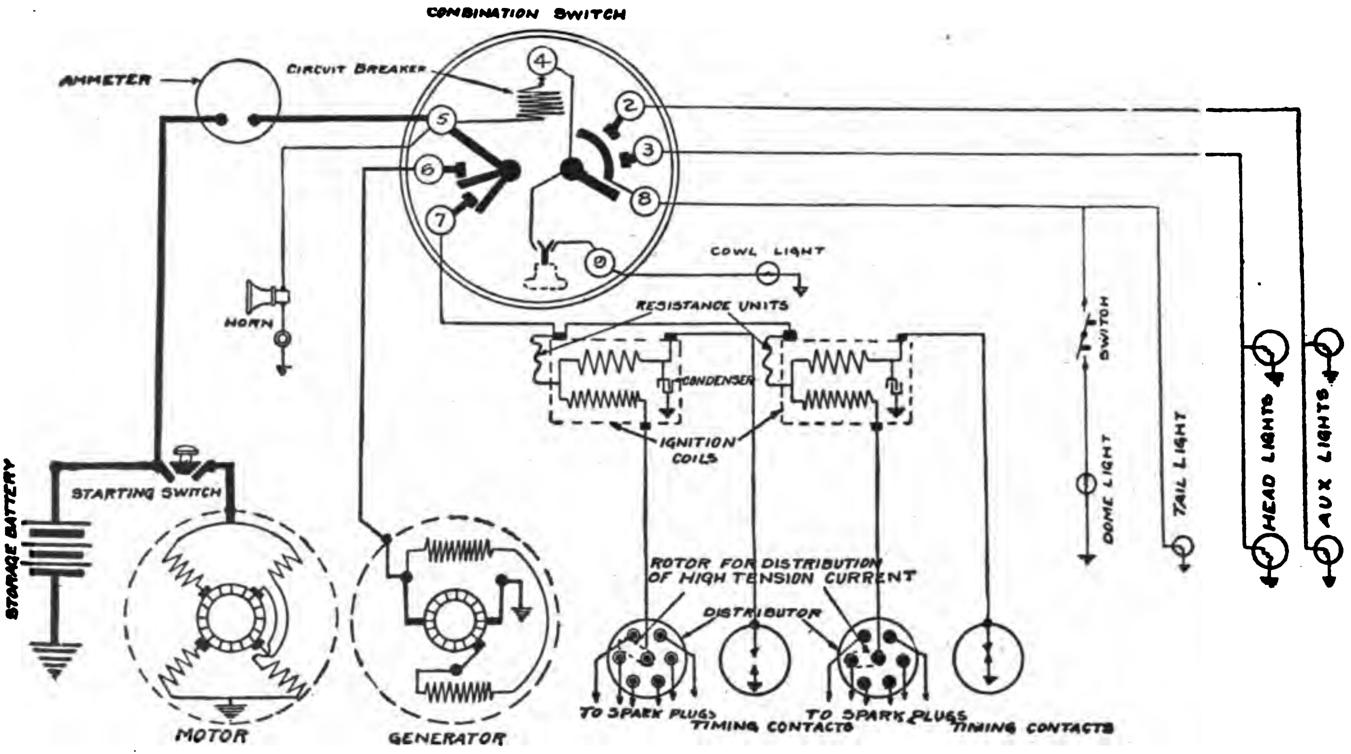


Fig. 257. Diagram Showing Method of Adjusting Third Brush in 1916 Delco Generator

Adjusting Third Brush. One of the advantages of the third-brush method of regulation is the ease with which the output of the generator may be varied. It has been found that on some of the 1916 models of the Delco system the generating capacity (as adjusted at the factory) has been set too high, especially for cars which are driven a great deal during the day and very little at night. As a result, considerable more current is generated than can be used to advantage. An indication of this will be found in the frequent necessity for adding water to the cells of the battery, or the fact that the battery is constantly gassing. In a case that recently came to the writer's attention, the owner of the car complained that the battery was no good because it was always *boiling*. It boiled so continually and so violently that it eventually had to be replaced. The complaint, in the average case, is that the battery is undercharged rather than overcharged. Unless trouble is experienced because of the battery gassing too much or needing water too frequently, the charging rate should not be altered. When necessary, the alteration may be made as follows: It will be noted in Fig. 257 that the third brush is carried on a brush arm made in two pieces and that the part to which the brush is fastened has a slot through which pass two screws, attaching it to the other part. By loosening these screws, one part may be slid on the other, thus increasing or decreasing the length of the arm. When the arm is shortened, the charging rate is decreased; and when the arm is lengthened the charging rate is increased. Care should be taken to sand-in the brush whenever it has been shifted in order to insure good contact with the commutator. (See Instructions for Seating Generator and Motor Brushes.) The screws on the brush arm must be firmly tightened after adjusting to prevent slipping.

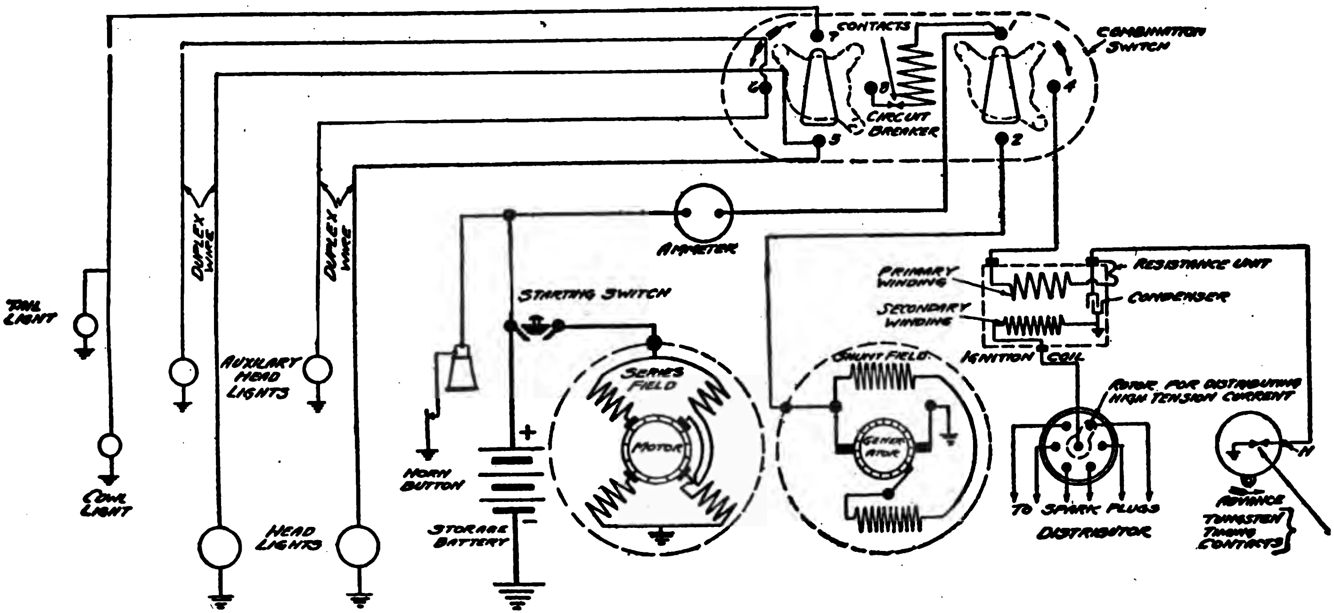
The charging rate of this type of Delco generator is higher at low-car speeds than on some machines of an earlier type, so that the maximum should be kept somewhat below the value that would be used for earlier machines. In most cases 14 to 16 amperes will be ample, and in no case should it exceed 20 amperes. Readings should be taken at the ammeter on the cowl switch, which indicates the amount of current going to the battery but does not include the ignition current.

The foregoing instructions for altering the charging rate apply only to machines having the third brush mounted on an adjustable arm, as different methods of moving the brush are provided on other types. The principle of adjustment, however, is always the same, i.e., moving the third brush closer to the nearest main brush increases the output and moving it away from this brush, decreases it. The third brush must never be allowed to come in contact with the main



87	**Generator**	2123	**Ignition Coil (2)**	86	**Motor**	1966	**Motor Switch**
5156	**Distributor**	1093	**Combination Switch**			6063	**Ammeter**

Delco Starting and Lighting Installation on the Kissel, 1917 Twelve-Cylinder Model



105 Generator
1075 Combination Switch

2139 Ignition Coil

107 Motor
1965 Motor Switch

Deloo Starting and Lighting Installation on the Liberty, 1917 Model brush. In the case of the Delco generator under consideration, the charging rate should reach a maximum at a speed of 15 to 20 miles per hour and then drop off as the speed increases beyond this point.

Tests of Wiring. *Locating Grounds.* By referring to any of the Delco diagrams of the one-wire type, it will be noted that certain parts of the circuits are normally grounded, i.e., they are connected to the common return represented by the chassis of the car. For example, the negative battery terminal, one terminal of each lamp, one motor, one generator brush, one timer contact, one terminal of the horn push button, and one terminal of the condenser in the coil are grounded. Before testing the wiring for grounds, it will accordingly be necessary to remove these normal, or intentional, grounds. This is carried out, in the order in which they are mentioned, by disconnecting the negative battery lead and removing all the lamps, placing a piece of cardboard between each generator and each motor brush, including the third brush of the former and the commutator against which it ordinarily bears, disconnecting the leads from the horn button and from the distributor, and raising the base of the ignition coil so that it is insulated from the top cover of the generator motor. The system will then be in the condition shown in Fig. 258.

One of the test points is then placed on the frame of the car and the other point on the negative terminal *A* of the battery. If the lamp lights, it will indicate a ground somewhere on the switch or in the motor windings (all of the switch buttons being pushed in). Then, with one test point still grounded on the frame of the car, test with the other point the different terminals of the combination switch. If the lamp lights during this test, it will indicate a ground on that particular circuit, which can be remedied without any particular difficulty.

Locating Shorts. To test for short-circuits between wires that are normally insulated from each other, place one test point on the end of one wire and the second test point on the end of the other, as shown in Fig. 259. If the lamp lights, it will indicate a short-circuit between these two wires, which can then be carefully inspected to locate the exact position of the fault. Failure of the lamp to light when the test is made will indicate that the wires in question are in good condition; the tests can then be applied to other parts of the circuits which should be insulated from each other.

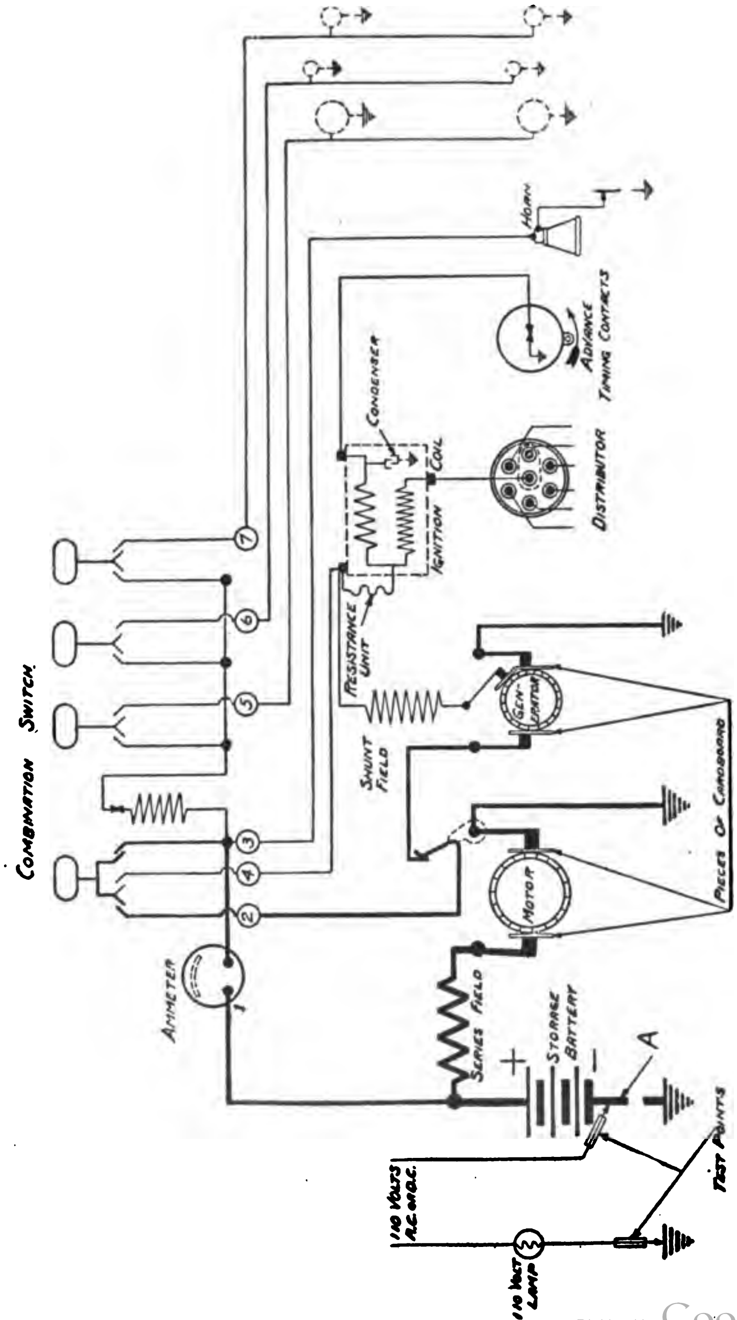


Fig. 258. Wiring Diagram Showing Method of Using Lamp-Testing Set for Locating Grounds
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

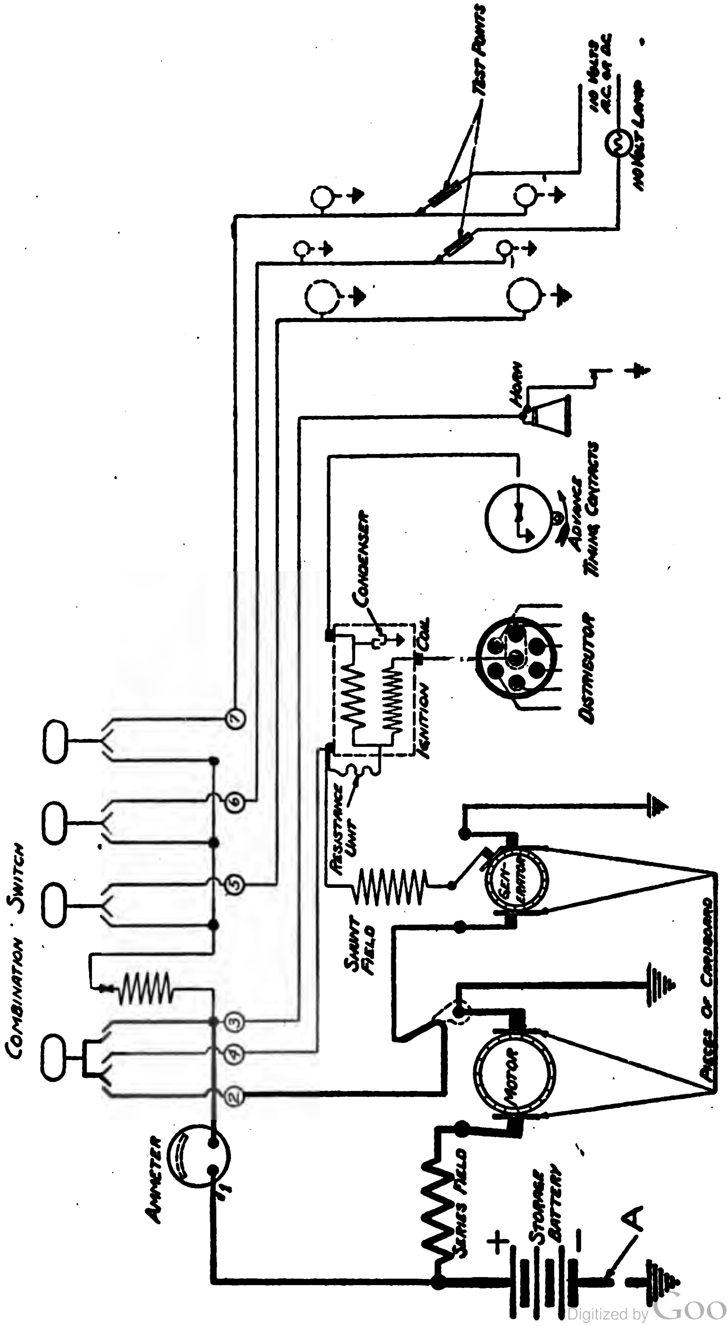


Fig. 259. Wiring Diagram Showing Method of Using Lamp-Testing Set for Locating Short-Circuits
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

Locating Breaks in Wires. Where the failure of the apparatus in a particular circuit makes it apparent that a wire, or lead, may be broken, it may be tested by placing one of the points on each end of the wire in question. The lighting of the lamp will indicate that there is a complete circuit through the wire, while its failure to light is evidence of a break in the wire. If at all difficult to locate the break, the easiest method of repairing it is to replace the wire with a new lead of the same size and type of insulation. The method of carrying out this last test is illustrated in Fig. 260 and it is naturally applicable to any of the wires, not only of this type of installation but of any other lighting and starting system. In making this test, care must be taken not to apply the points at places on the terminals where a ground connection will result, as this will complete the circuit through the lamp without the current passing through the wire supposedly under test. This method of locating grounds, short-circuits, or open circuits will be found much better than the use of a buzzer, bell, or magneto, and it is recommended wherever a 110-volt current is available. However, where it is not available, a lamp, bell, buzzer, or the portable voltmeter may be used in connection with the storage battery on the car, after detaching its usual connections to the system.

Testing Cut-Out. If the battery is not charging properly, the generator being in good condition, or it is discharging too much current through the cut-out, the latter should be tested and adjusted to remedy the trouble. The cut-out is designed to close when the voltage across the terminals of the voltage coil is 6½ to 7¾ volts. To check this a voltmeter should be connected across the terminals, noting the reading at the point that the contacts close. It is designed to break the circuit when the discharge current is less than 1 ampere, preferably as close to the zero mark as possible to reduce the arc on breaking the contacts. This can be checked by placing an ammeter in the circuit in series with the current coil of the cut-out, noting the value of the current at the moment that the contacts separate. When properly adjusted the air gap should be $\frac{1}{32}$ inch.

To adjust the cut-out, the influence of both the air gap and of the spring tension must be taken into consideration. The air gap has little or no effect upon the point of cut-out, this being governed almost entirely by the spring tension, whereas the point of cutting

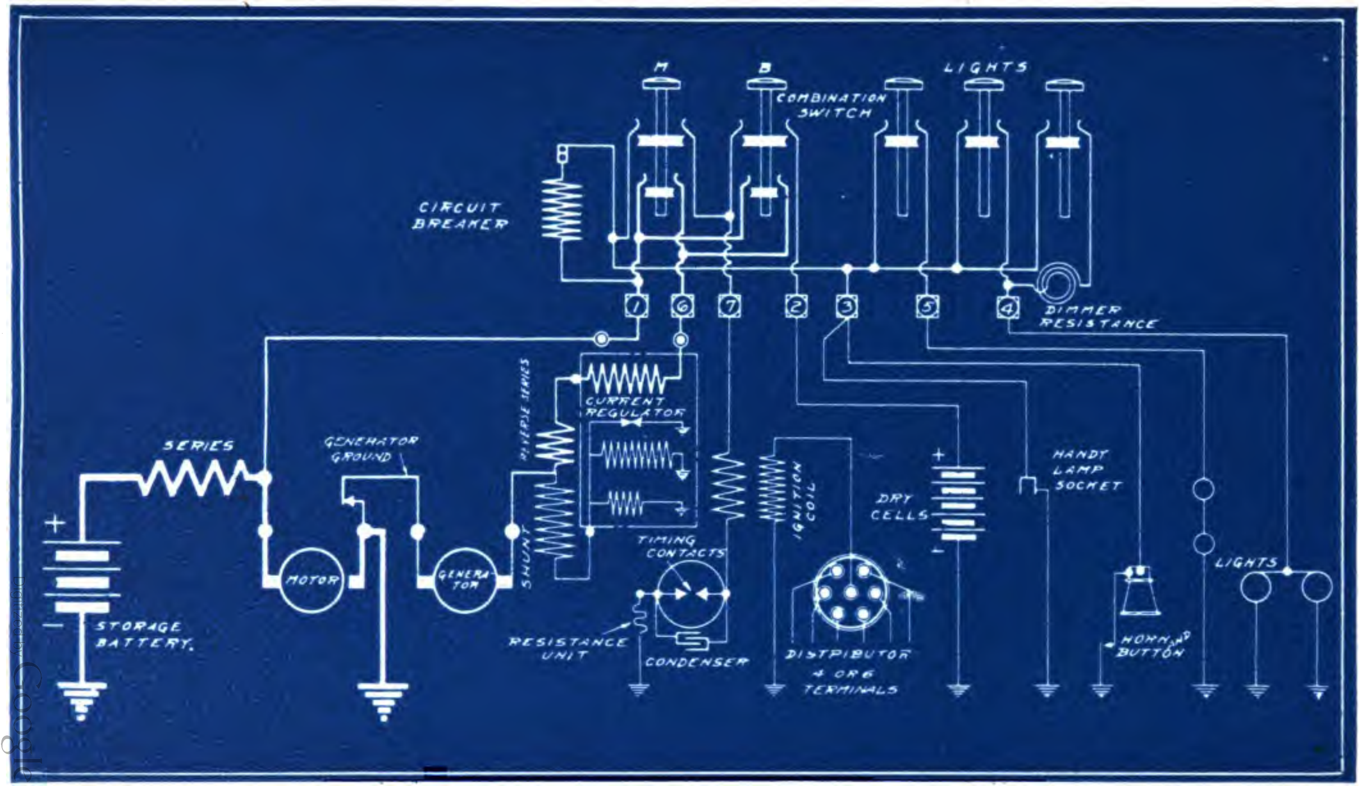


PLATE 28—DELCO CIRCUIT DIAGRAM FOR COLE 1915 CARS, MODEL 4-40

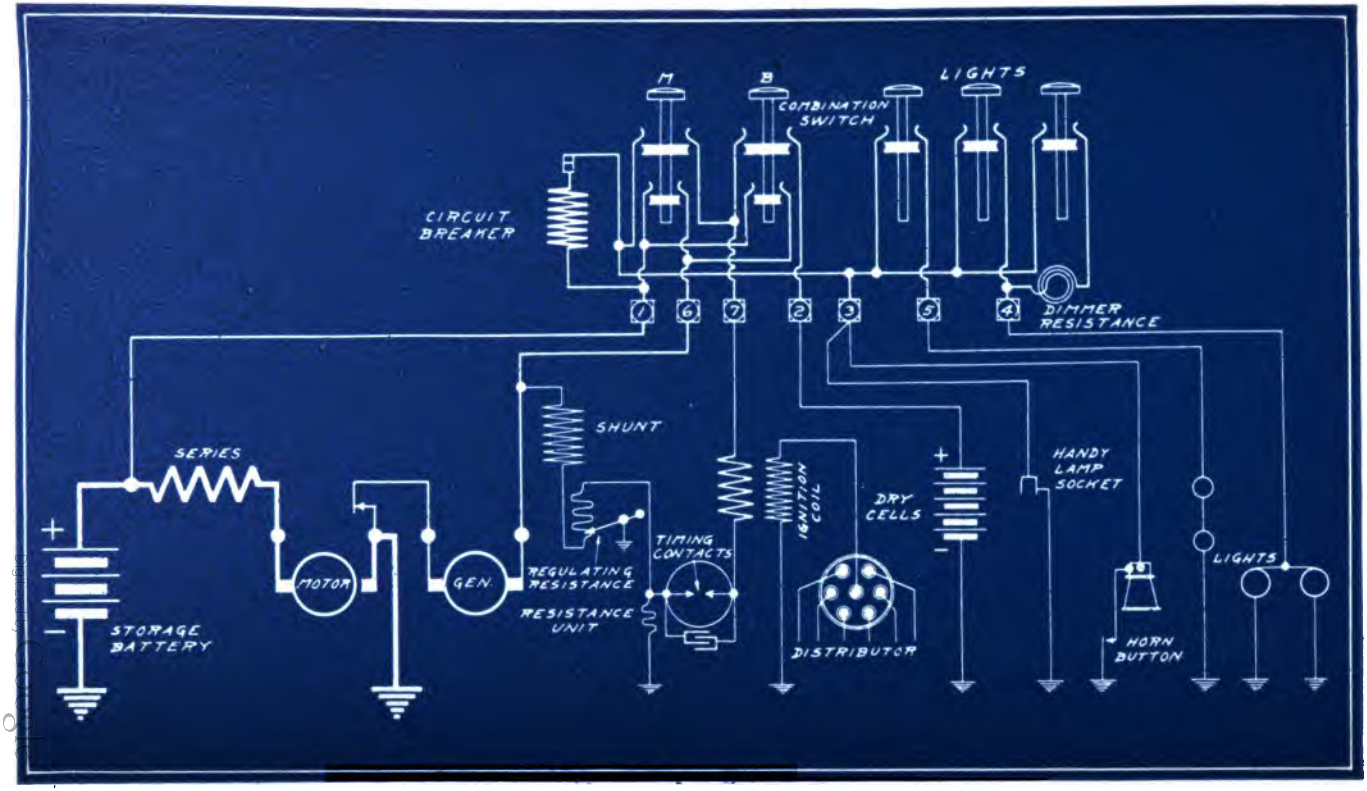


PLATE 29—DELCO CIRCUIT DIAGRAM FOR COLE 1915 CARS, MODEL 6-50

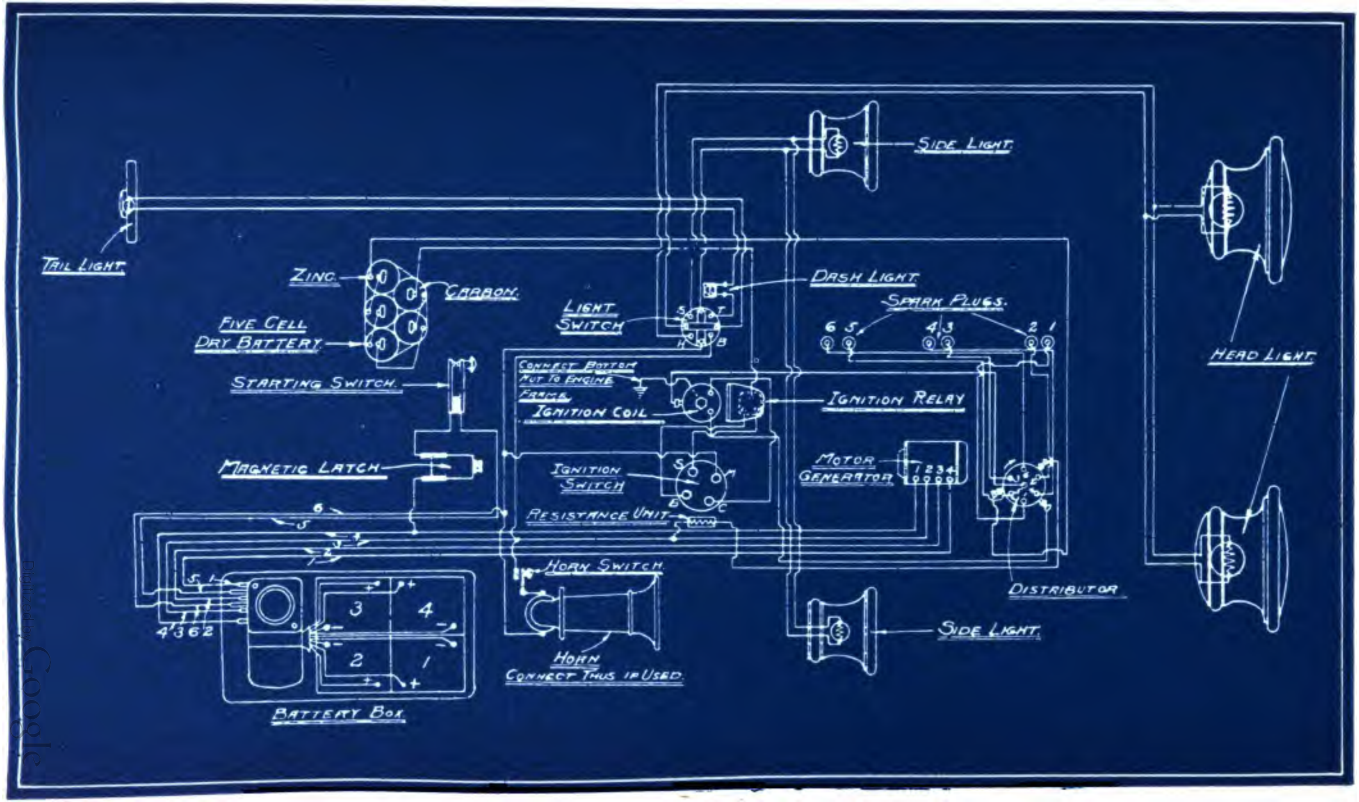


PLATE 30—DELCO WIRING DIAGRAM FOR COLE 1913 CARS, MODELS 4-40, 4-50 AND 6-60

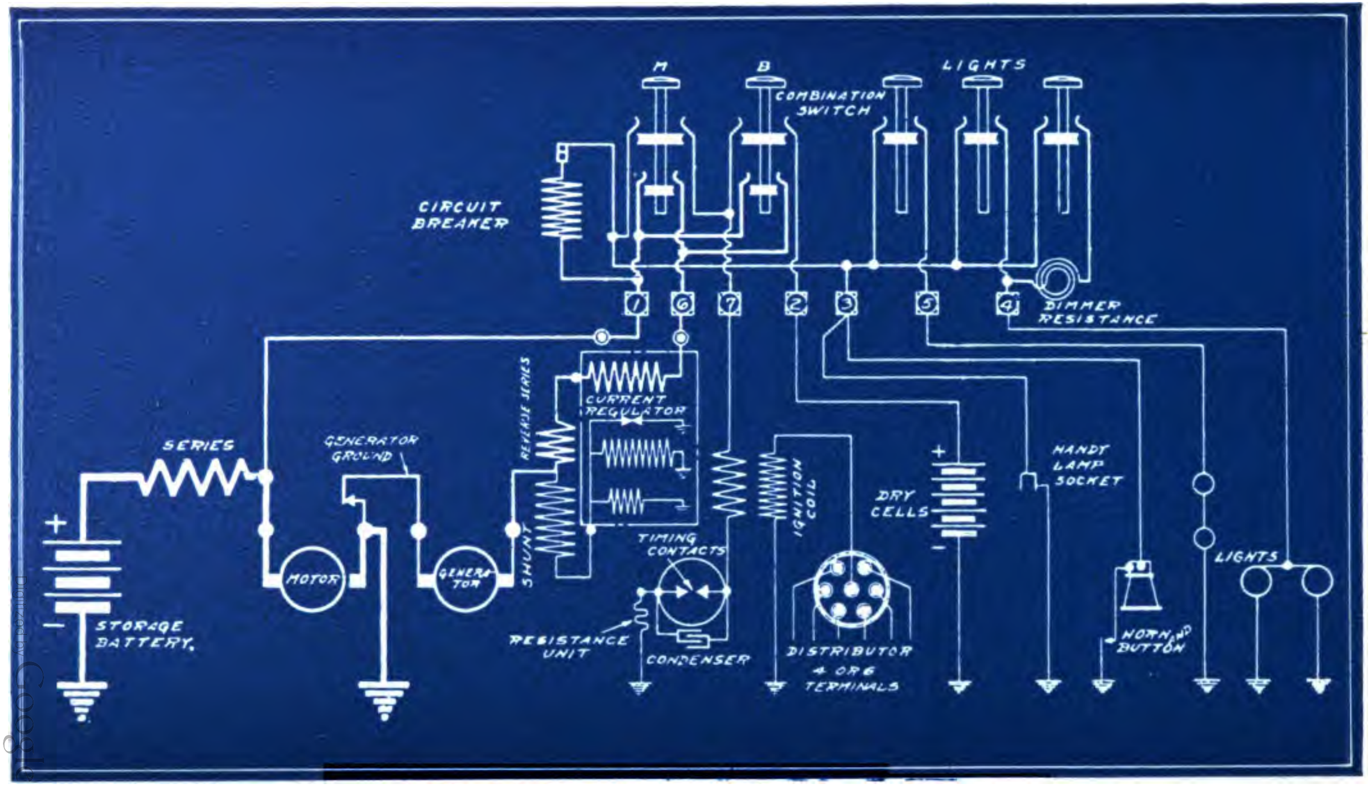


PLATE 81—DELCO CIRCUIT DIAGRAM FOR COLE 1913 CARS, MODEL 4-40

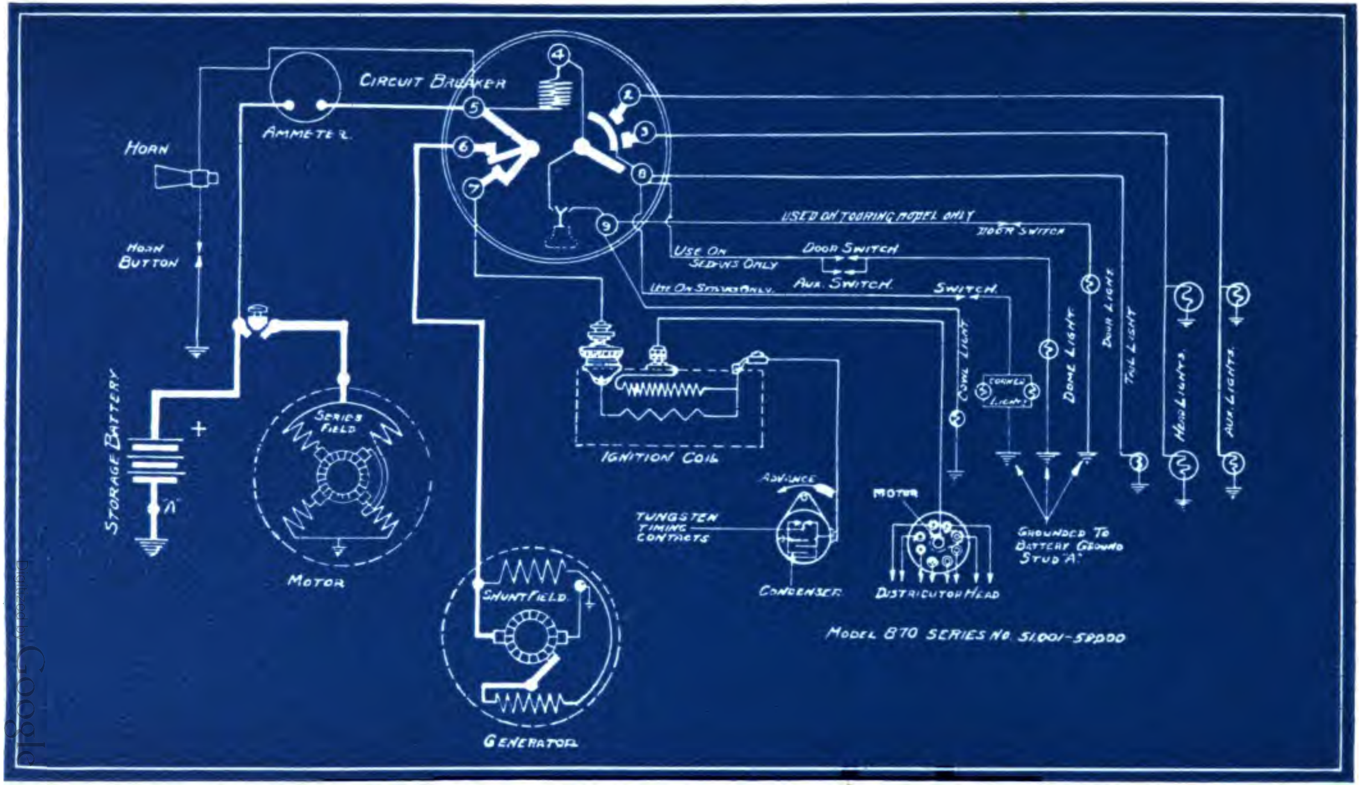


PLATE 32—DELCO CIRCUIT DIAGRAM FOR COLE 1918 CARS, MODEL 870

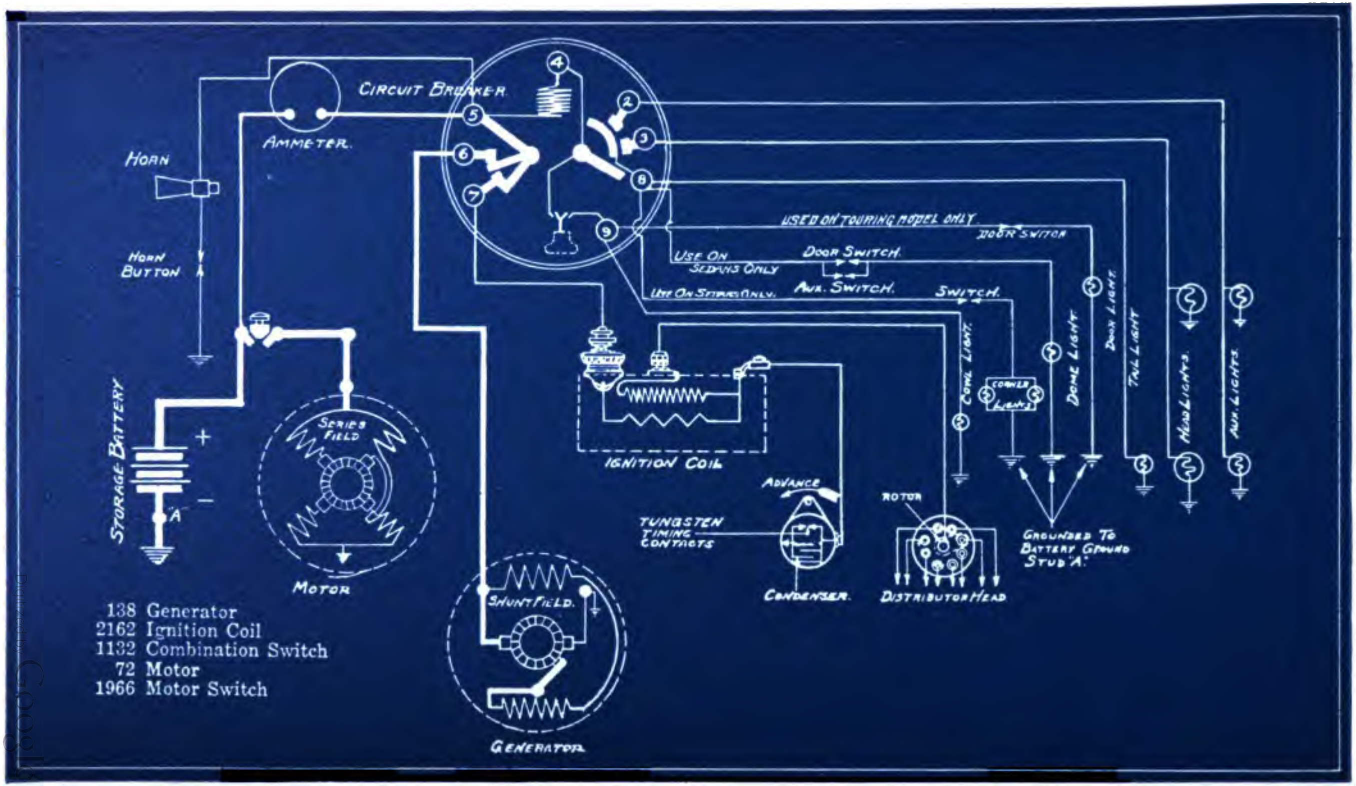
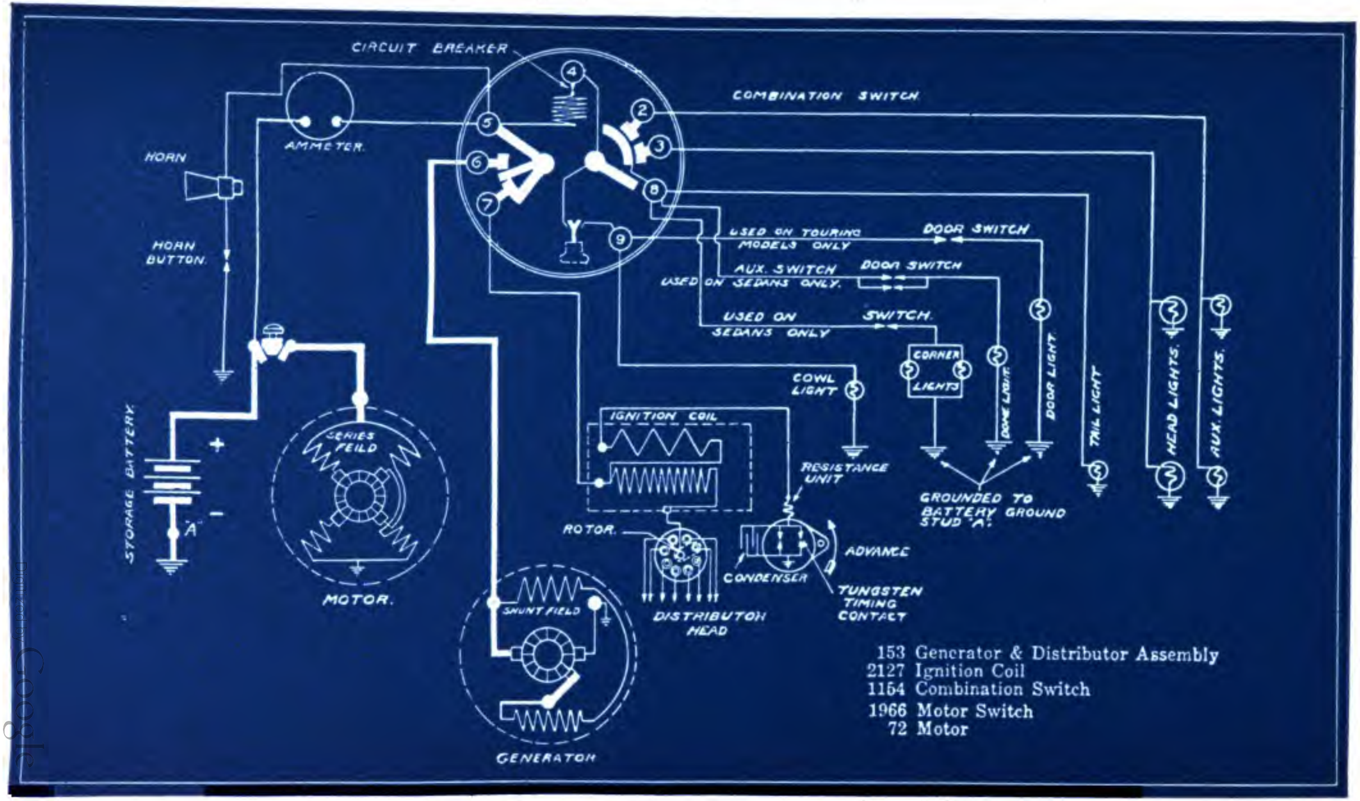


PLATE 32A—DELCO WIRING DIAGRAM FOR 1919 COLE, MODEL 870, SERIAL Nos. 51001-54000



153 Generator & Distributor Assembly
2127 Ignition Coil
1154 Combination Switch
1966 Motor Switch
72 Motor

PLATE 32B—DELCO WIRING DIAGRAM FOR 1920 COLE, MODEL 870, SERIAL Nos. 57200 AND UP

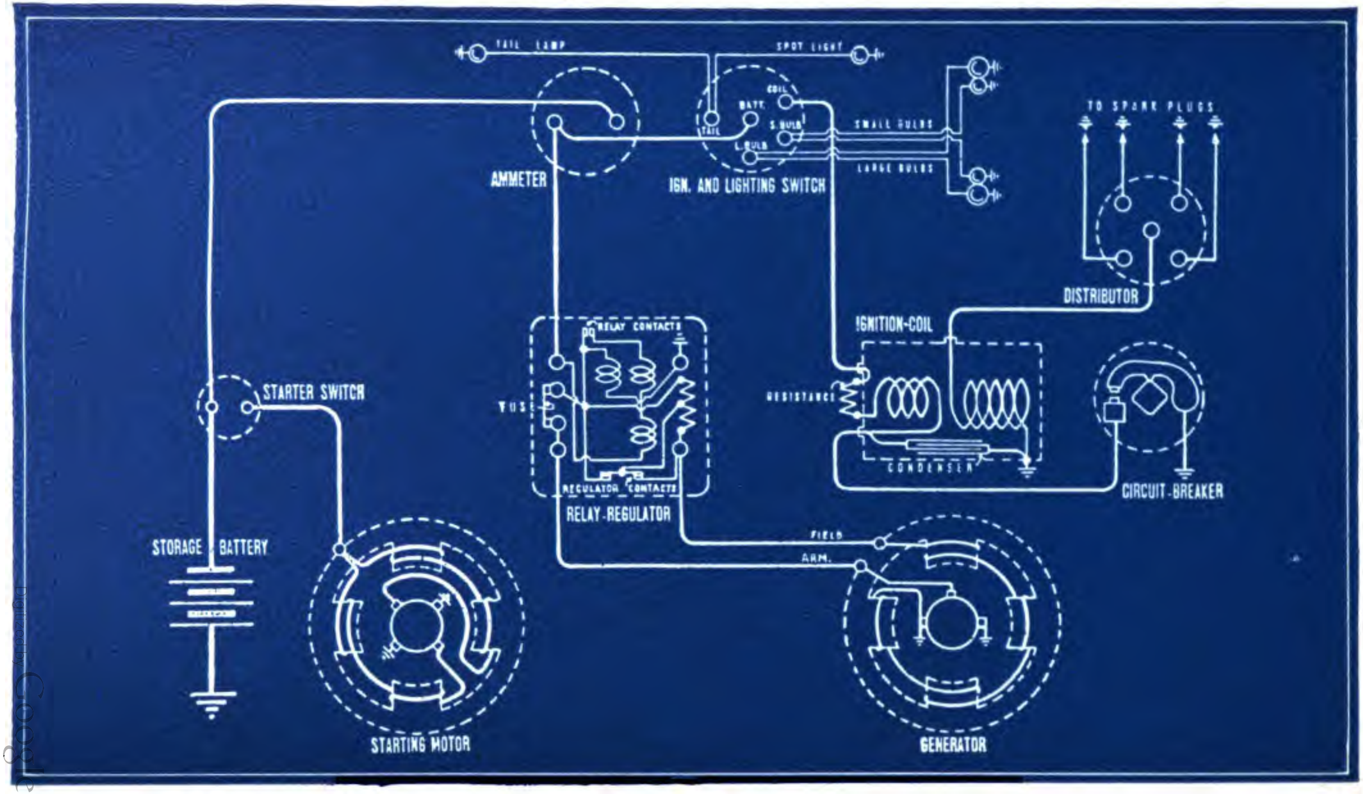


PLATE 33—REMY WIRING DIAGRAM FOR COMMERCE CARS, MODEL E

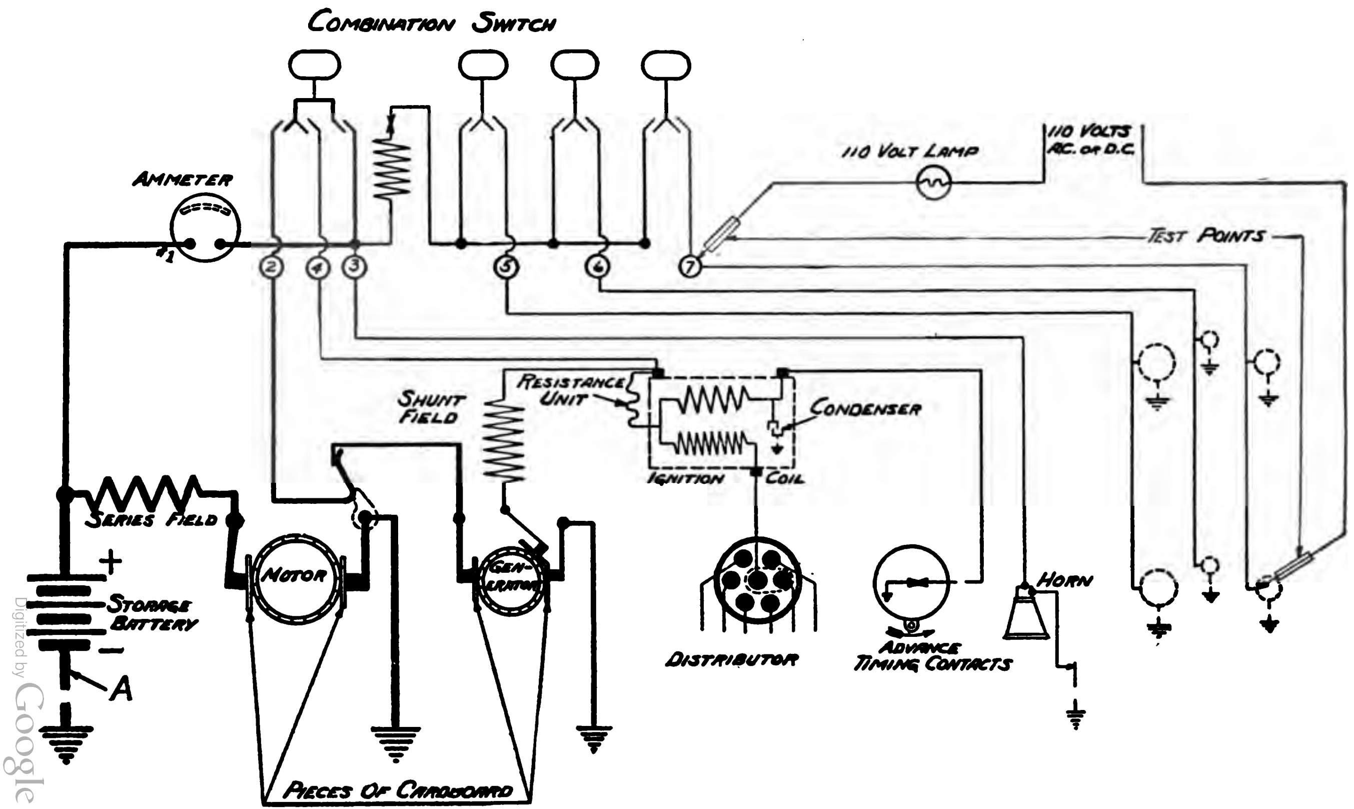


Fig. 260. Wiring Diagram Showing Method of Using Lamp-Testing Set for Discovering Breaks in Wires
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

in is governed by both the air gap and the spring tension. The following examples will illustrate the adjustments necessary in cases of excess voltage and current, excess voltage alone, insufficient voltage and excess current, and insufficient voltage alone.

Where the relay cuts in at 8 volts and cuts out when the discharge current is 2 amperes: Decrease the air gap, as this will lower the voltage of the cut-in point, but it will also increase the discharge current on cutting out. To overcome the latter, increase the spring tension slightly, noting the effect on the ammeter until the latter registers less than 1 ampere on cutting out.

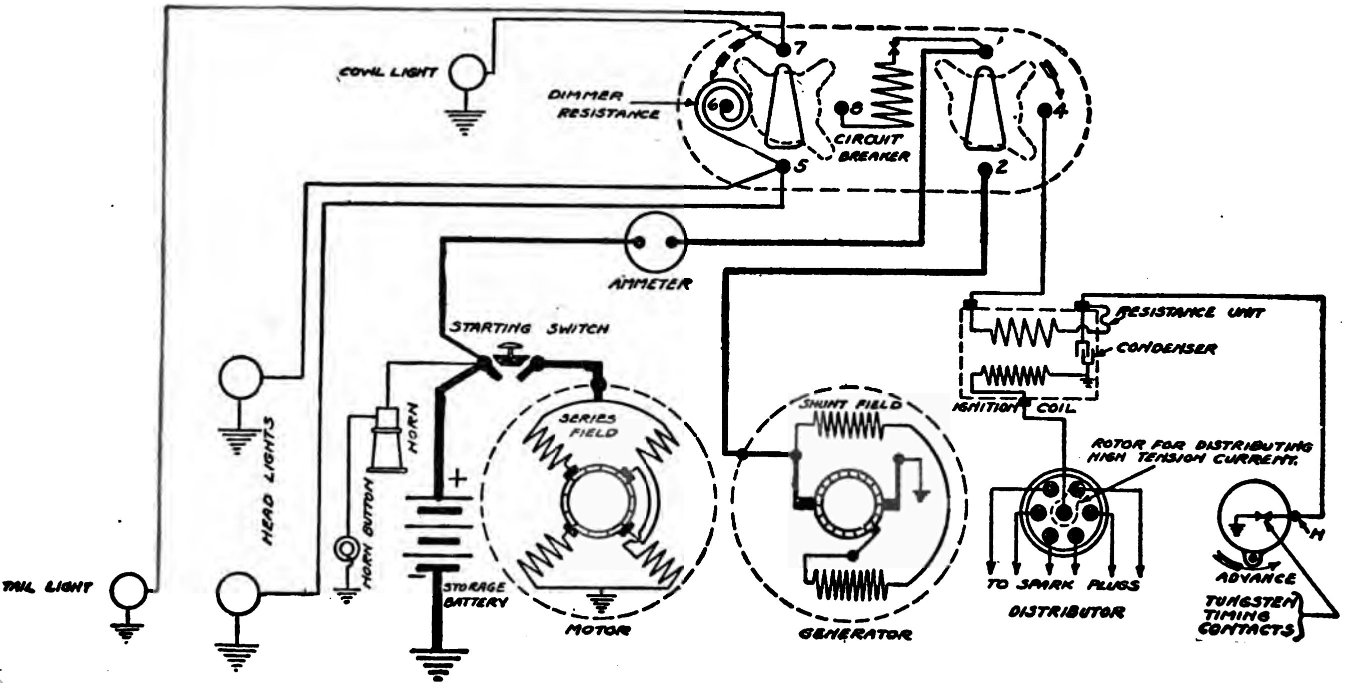
Where the relay cuts in at 8 volts and cuts out at 1 ampere: Decrease the spring tension as this will cause the relay to cut in at a lower voltage and also to cut out after the current starts to discharge through it.

Where the relay cuts in at 6 volts and cuts out at 2 amperes: Increase the spring tension, causing the relay to cut in at a higher voltage and also to cut out at a discharge-current value of less than 2 amperes.

Where the relay cuts in at 6 volts and cuts out with a discharge current of 1 ampere: Increase the air gap slightly and also increase the spring tension so as to cause the relay to cut in at a higher voltage and also cut out at a discharge current of less than 1 ampere.

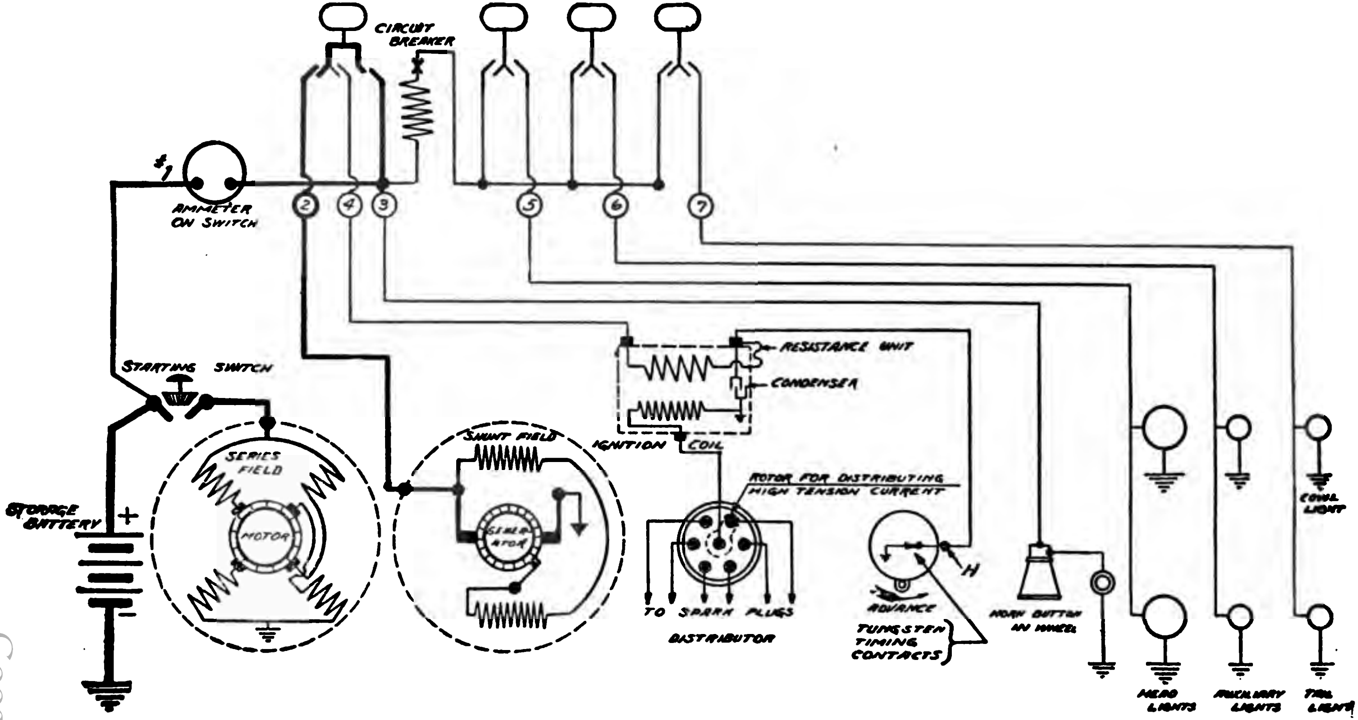
In this connection *cut in* signifies the closing of the contacts when the voltage coil becomes energized as the generator starts up; *cut out* indicates the opening of the generator battery circuit when the current from the battery reverses the polarity of the current coil of the relay, thus opening the circuit and cutting out the generator from the battery circuit when the generator slows down and there is insufficient voltage for charging the battery. While these instructions apply particularly to the Delco relay or cut-out, all devices of this nature operate on the same principles.

Before making any adjustments, the contact points should be examined. If they are blackened or pitted, take two narrow strips of emery cloth about $\frac{3}{8}$ inch wide and both the same length. Place them together, emery sides out, insert between the contacts and while an assistant holds the points together, draw back and forth. If no assistance be obtainable, use a single strip and apply alternately to each contact point until its face is bright all over and true



105	Generator	106	Motor
1078	Combination Switch	1966	Motor Switch
8139	Ignition Coil	6063	Ammeter

Delco Starting and Lighting Installation on the Moon, Model 6-43



101 Generator
1081 Combination Switch

2139 Ignition Coil

108 Motor
1964 Motor Switch

Delco Starting and Lighting Installation on the Moon, Model 6-66 so that when the two points come together they touch evenly all over their surfaces. Do not take off any more than is necessary for this purpose, particularly where the contacts are platinum, as this simply wears them away uselessly and they are very expensive to replace. After cleaning, test for cutting in voltage and cutting out current and it frequently will be found that no adjustment is necessary.

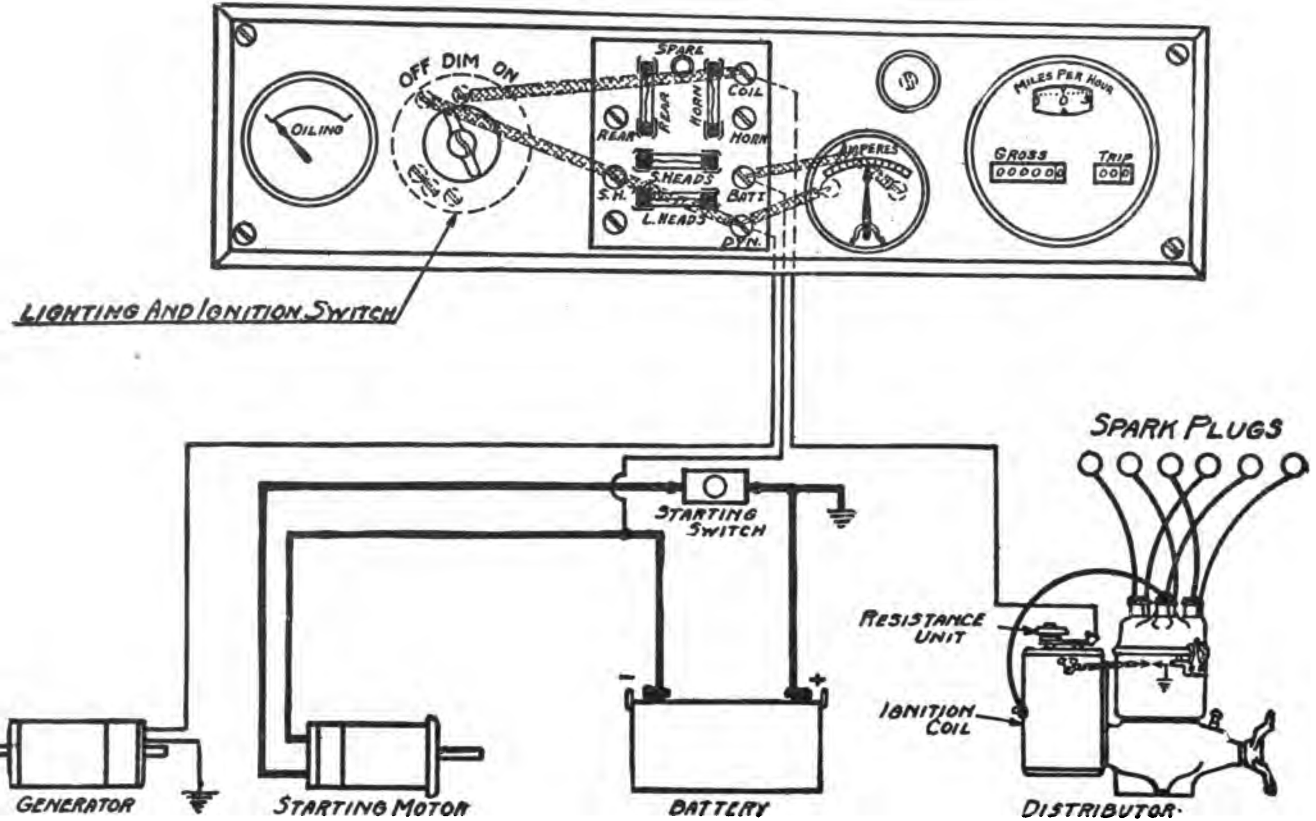
These instructions regarding the cleaning of contact points apply with equal force to all instruments having contacts by means of which the circuit is frequently made and broken, for even platinum is burned away by the electrical action of the current which tends to carry the metal of the positive contact over to the negative in finely divided form, thus making a hole, or crater, on the positive and a cone, or peak, on the negative.

If the contacts are too badly burned to permit of their being put in good condition in this way, it will be necessary to replace them. After the relay has been reassembled with the new contacts, it should be adjusted in accordance with the instructions already given. When the contacts are correctly adjusted, both pairs will make contact at the same instant and clear across the line of contact so that when the relay is held up to the light, it is impossible to see light passing through any portion of the line of contact. When adjusting the relay make sure that all insulating bushings are in good condition and that the connections and coil terminals are free from breaks or grounds, as these would cause uncertainty in its operation..

Testing Circuit-Breaker. In case the circuit-breaker vibrates constantly, it indicates a ground in one of the circuits. Should it continue to vibrate when all of the buttons of the combination switch have been pushed in, the ground will almost invariably be found in the horn or its connections. In case no ground can be found in any of the circuits with the aid of the testing lamp, and the circuit-breaker still continues to vibrate, connect the portable testing ammeter in the circuit, using the 30-ampere shunt. Then hold the circuit-breaker closed and note the ammeter reading when it opens. This must be done quickly as the current necessary to keep it operating is small so that the ammeter reading will quickly drop to a value of 3 to 5 amperes. However, the circuit-breaker should not open on a current of less than 25 amperes. If the ammeter reading indicates that it does so, increase the tension of the spring until the current necessary to operate it shows that it is properly adjusted. In case the instrument shows that the circuit-breaker is opening at the proper point but still continues to vibrate, another series of tests for a ground must be made as the latter is the cause of the trouble.

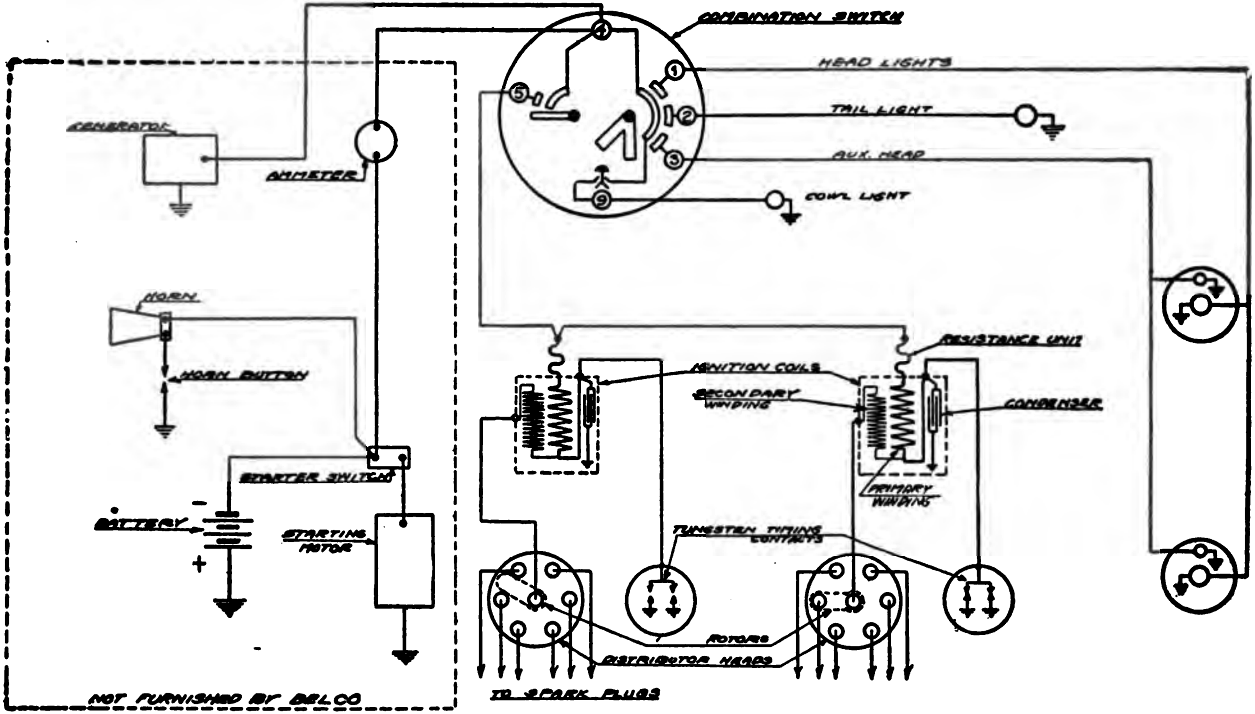
Seating the Brushes. To insure proper operation of the machine either as a generator or as a motor, it is necessary that the brushes fit the commutator exactly and that they make good contact over their entire surface. If they do not, sparking will occur and the commutator will become burned and blackened, cutting down the efficiency of the machine. The brushes are the only wearing parts of a direct-current generator or motor, and, as this wear on them is constant, they will require attention at intervals to keep them in good condition. Whenever sufficient wear has taken place to make the contact uneven, the brushes must be fitted to the commutator or *sanded-in*. Cut a sheet of No. 00 sandpaper in strips slightly wider than the brush. Emery cloth must *never* be used for this purpose. It is metallic and will tend to cause short-circuits in the commutator. The strip of sandpaper is wrapped around the commutator so as to make contact with at least half of its circumference in the manner illustrated in (*a*) and (*c*) of Fig. 261. The smooth side of the paper is laid on the commutator so that the sanded side rubs the brush. By drawing the sandpaper back and forth, it is possible to fit the brush very accurately to the commutator. It will be obvious that if the sandpaper be applied to the commutator, as shown in (*b*) and (*d*) of the same illustration, that the brush will only touch at its center and there will be excessive sparking between the gaps thus formed.

A high squeaking note caused by the operation of either the generator or motor is an indication that either the brushes or the commutator need sanding-in as the latter will become roughened from the wear. It should be smoothed up by taking strips of the same grade of sandpaper sufficiently wide to cover the commutator, applying them by wrapping in the same manner but with the sanded surface on the commutator bars. This can be done most effectively by running the machine through its other commutator



5163 Distributor including one 2155 Coil

Delco Starting and Lighting Installation on the Nash, Model 681



5168 Distributor including two ignition coils No. 2152 1088 Combination Switch

Delco Ignition Installation on National Twelve-Cylinder Cars, Series A-K for a few moments while holding the sandpaper strip in place on the first. If, after this smoothing up, the mica insulation between the bars of the commutator is flush with the surface of the copper bars, it must be undercut as directed in the following section. On most of the Delco machines it will be found possible to sand-in the upper and lower brushes separately by this method, but in a number of cases on account of the construction of the machine, it will be found advisable to sand-in both motor brushes, as well as both generator brushes at the same time. It is unnecessary to lubricate either the motor, the generator brushes, or the commutators, as this simply results in gumming them and causes grit and dirt to collect on the commutator and cut grooves in both it and the brushes.

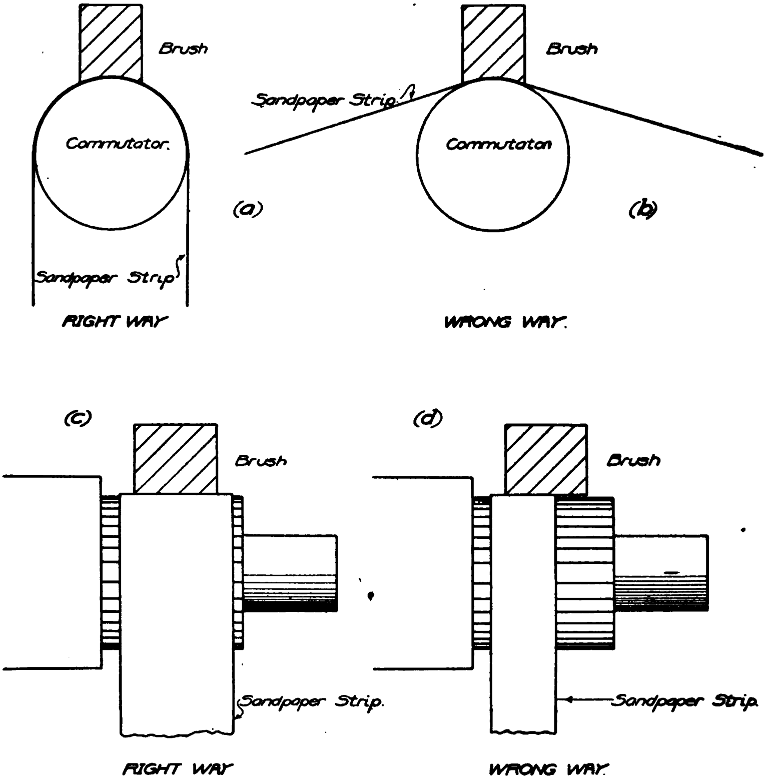


Fig. 261. Method of Sanding-In Brushes
Courtsy of Auto Electric Systems Publishing Company, Dayton, Ohio

Commutator Maintenance. In the course of time, the commutator bars of the generator will wear down until they are flush with the mica insulation separating them. When this occurs there will be excessive arcing in the brushes which, in turn, will cause the copper to be burned away until it is level with, or below, the surface of the mica. This condition will be indicated by a rusty black color on the commutator bars. To prevent this condition, the commutator should be cleaned occasionally with sandpaper as directed. If the mica is *high*, it should be undercut as follows:

The armature is removed from the machine and placed in a lathe, truing up both commutators until they are perfectly concentric. This should be done carefully and then as fine a cut as possible taken to avoid wasting the copper needlessly. When the commutators have been trued up in the lathe, cut out mica between the commutator bars of the generator only. For this purpose a piece of hacksaw blade should be fixed in a handle, as shown in Fig. 262, and its teeth ground off until they will cut a slot that is just slightly wider than the mica insulation. The cut need not be more than $\frac{1}{32}$ inch deep. In this way a rectangular slot, free from mica, will be obtained between each two adjacent commutator bars. After undercutting the mica, the edges of these slots should be beveled very slightly with a three-cornered file in order to remove any burrs which would cause excessive wear of the brushes.

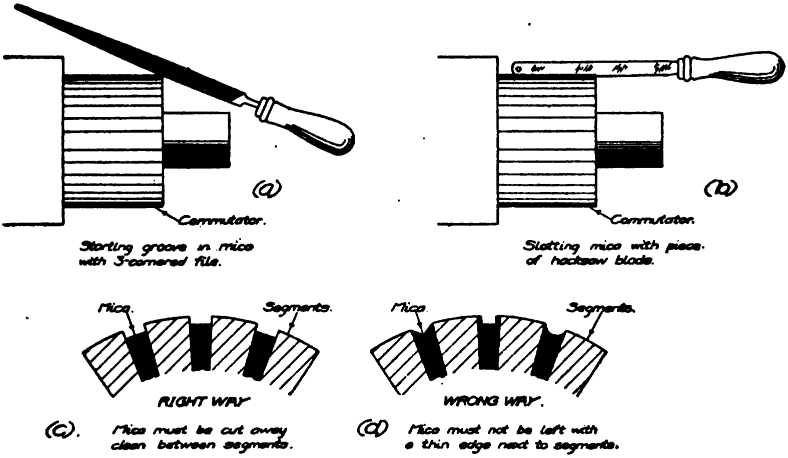
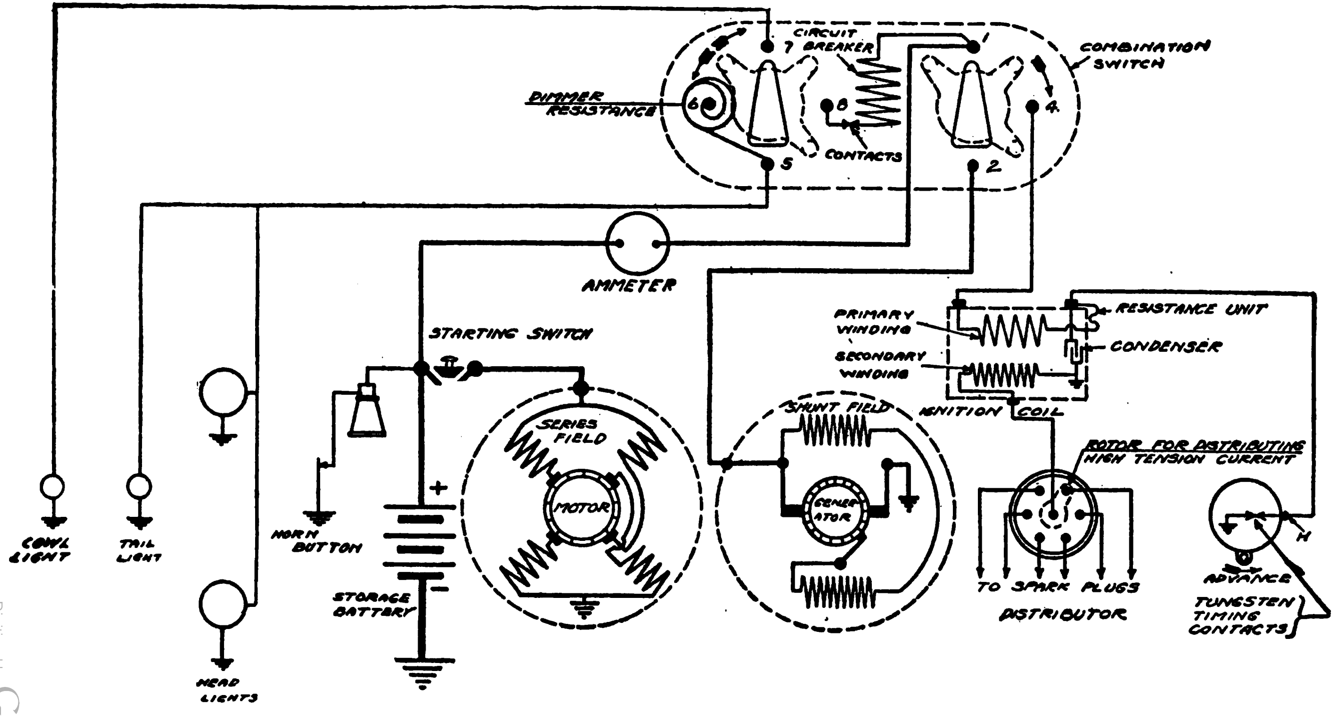

(a)
Commutator.
Starting groove in mica with 3-cornered file.
(b)
Commutator.
Slotting mica with piece of hacksaw blade.
Mica.
Segments.
RIGHT WAY
(c). Mica must be cut away clean between segments.
Mica.
Segments.
WRONG WAY.
(d) Mica must not be left with a thin edge next to segments.

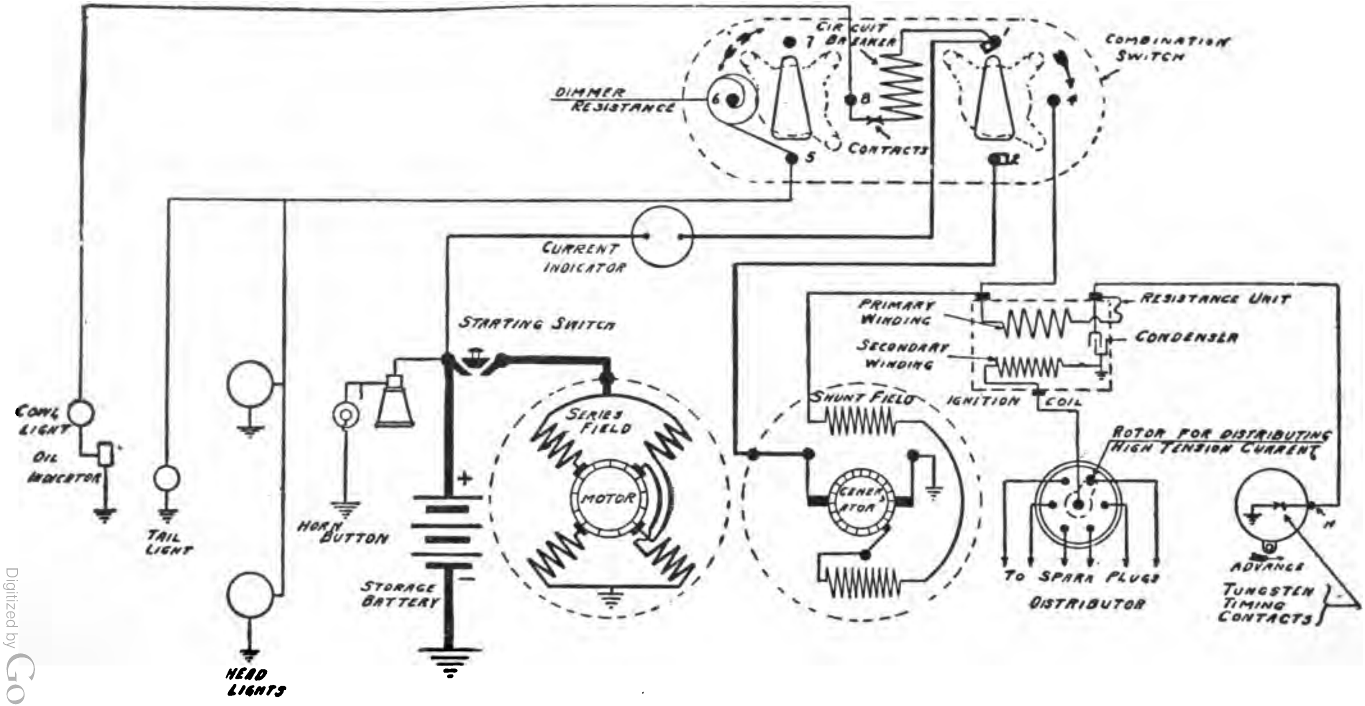
Fig. 262. Method of Undercutting Mica Insulation on Commutator
Courtesy of Auto Electric Systems Publishing Company, Dayton, Ohio

It is unnecessary to undercut the mica on the motor commutator, as, wherever metal or metallic brushes are used on Delco machines, they are sufficiently hard to keep the mica flush with the surface of the copper as it wears down without any undue arcing at the brushes, whereas in the case of generators provided with



99	**Generator**	2137	**Ignition Coil**	100	**Motor**
1078	**Combination Switch**			1965	**Motor Switch**

Delco Starting and Lighting Installation on the Oakland 1917 Cars, Model 32-B



111 **Generator**
1078 **Combination Switch**
1965 **Motor Switch**
2137 **Ignition Coil**
100 **Motor**

Delco Starting and Lighting Installation on the Oakland, Model 34 carbon brushes, the carbon is not hard enough to do this. After completing the undercutting, the commutator when viewed from the end should show clean-cut rectangular slots between the bars, as in the left-hand view, Fig. 262. The machine should then be reassembled and the brushes sanded-in to the commutator, as previously described. This operation of fitting the brushes to the commutator will be necessary whenever anything has been done to the commutator, when new brushes are installed, or when the third-brush location is readjusted to vary the output of the machine on generators having this type of regulation.

These instructions for fitting the brushes, cleaning the commutator, and undercutting the mica of the commutator of any machine equipped with soft-carbon brushes, apply with equal force to all makes of generators and starting motors employed on automobiles. Next to the battery the brushes and commutators will be found to demand most attention—or to put it another way, they will be found to constitute a cause of trouble only second in importance to the battery. It must not be assumed, however, that all blackening of the commutator is caused always by high mica. Any one of the following conditions may cause the commutator to assume an appearance similar to that produced by high mica: (1) generator brushes of improper size or material, as where replacements other than those supplied by the manufacturer of the machine have been installed; (2) insufficient spring tension on brushes—all springs slacken up in time and they should be examined at intervals to see that the brushes are being held firmly against the commutator; (3) overloading of the generator caused by partial failure of the regulating device or other cause; and (4) an open- or short-circuit in the generator windings, or a short-circuit between generator and motor windings in a single-unit machine like the Delco.

Testing Armatures. In reading the foregoing instructions as well as those that follow here concerning the Delco system, it should be borne in mind that they apply in principle, and in many cases in actual detail, to the majority of other systems described. In other words, all starting and lighting systems are based on the same principles and, while many of them differ in detail and in design, the application of the instructions in question will very frequently be evident by comparing them point for point and modifying the instructions to compensate for any slight differences in design or wiring.

Armature troubles are of much less frequent occurrence than the majority of defections, such as worn brushes, dirty commutator, or the like, which temporarily put the system out of commission, so that every part of the system which might be at fault should be investigated before attempting to test the armature for faults. To carry out these tests, the voltmeter and the lamp-testing set are necessary. Where no previous experience has been had in making tests with these aids, it will be well to become familiar with the detailed instructions given for their use in connection with the determination of other faults, as already described. It is not necessary to remove the dynamotor from the car for this purpose. When tests of the remainder of the system indicate no faults and when grounds in the armature windings or short-circuits between them are not suspected, raise all the brushes from the commutator and slip pieces of cardboard between the brushes and the commutator so as to insulate them from each other. These instructions cover the single-unit Delco machine, so the foregoing applies as well to testing for short-circuits between generator and motor armature windings. For greater simplicity, the possible faults and the tests for locating them are treated under different heads, as follows:

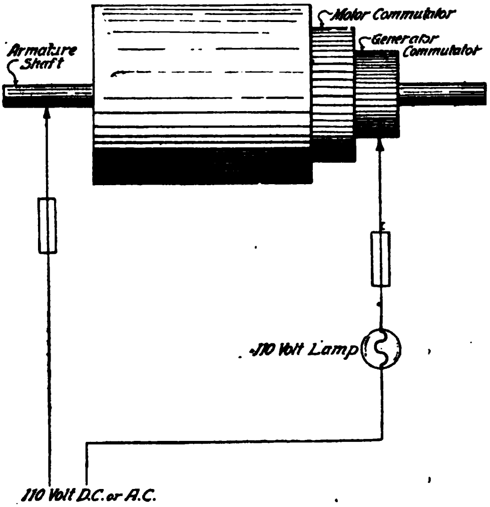
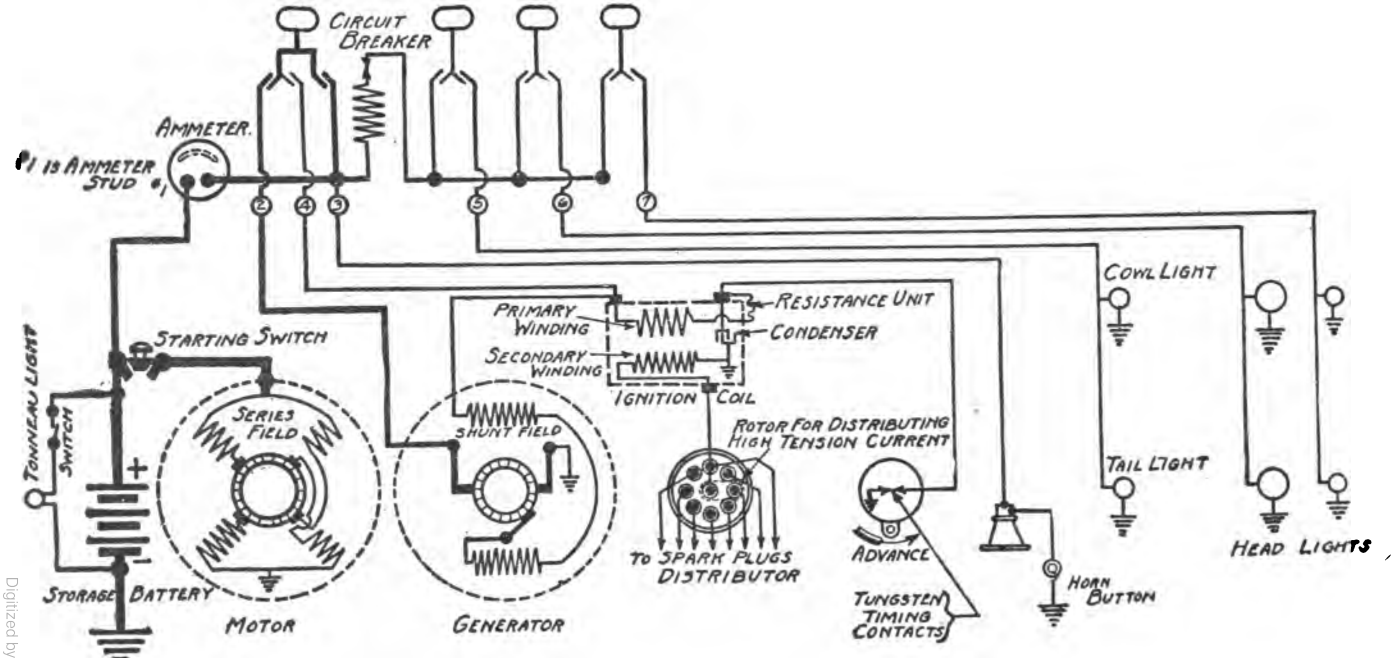


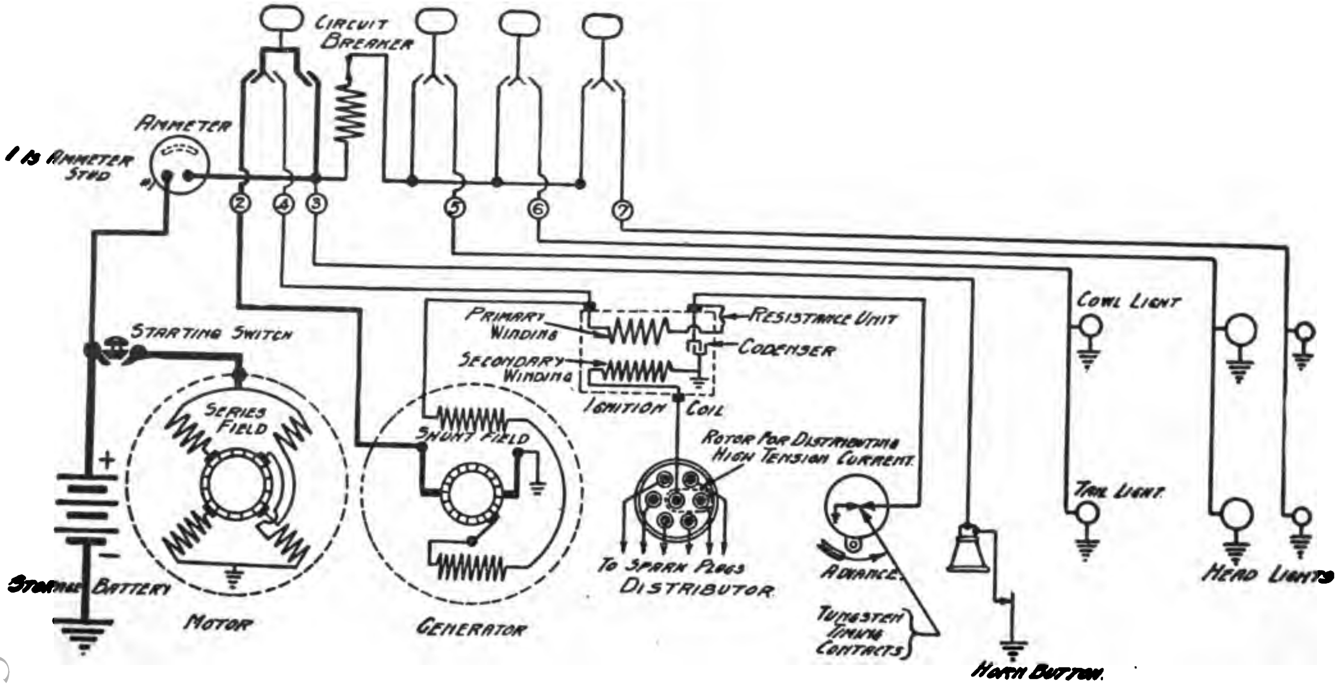
Fig. 263. Diagram for Locating Grounded Generator Coil with Lamp-Testing Set

(a) *Grounded Generator Coil.* On one-wire systems of the single-unit type, the presence of a grounded generator coil will materially reduce the charging rate to the battery and will also result in slow cranking of the engine. To determine whether a generator coil has become grounded, place one of the test points on the frame or on the armature shaft, both of which are grounded, and the other on the generator commutator, as shown in Fig. 263. If the lamp lights, it indicates a ground on the commutator. The test of the generator of a two-unit set would be carried out in exactly the same manner.



113	**Generator**	1066	**Combination Switch**
5158	**Distributor**	72	**Motor**
2153	**Ignition Coil**	1966	**Motor Switch**

Delco Starting and Lighting Installation on the Olds 1917 Cars, Model 45



111	**Generator**
1066	**Combination Switch**
2137	**Ignition Coil**
100	**Motor**
1966	**Motor Switch**

Delco Starting and Lighting Installation on the Olds 1917 Cars, Model 45A

(b) *Grounded Motor Coil.* According to the nature of the fault, a grounded motor coil may either prevent operation of the starting motor altogether or it may result only in an excessive consumption of current for starting. The test is carried out in the same manner as described for the generator, except that the second point of the test set is placed on the motor commutator, Fig. 264. It will likewise be evident that an independent starting motor can be tested in the same way.

(c) *Short-Circuits between Motor and Generator Armature Coils.* In most cases short-circuits between motor and generrator armature coils will decrease the speed of cranking and will cause the armature to continue to run after the engine has been shut down. This test is carried out by simply placing one test point on the generator commutator and the other on the motor commutator. If the lamp lights, it indicates a short-circuit between the generator and motor windings, Fig. 265. This test is

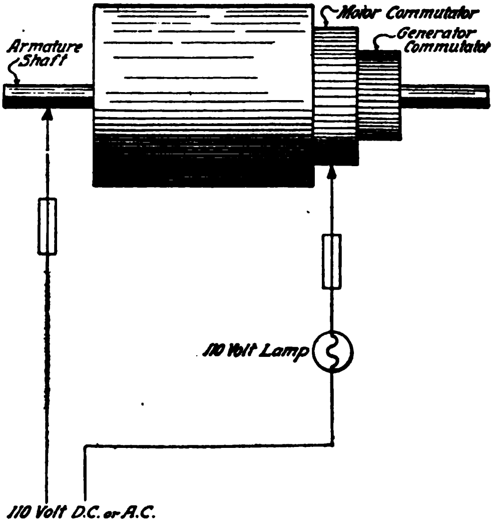


Fig. 264. Diagram for Locating Grounded Motor Coil with Lamp-Testing Set

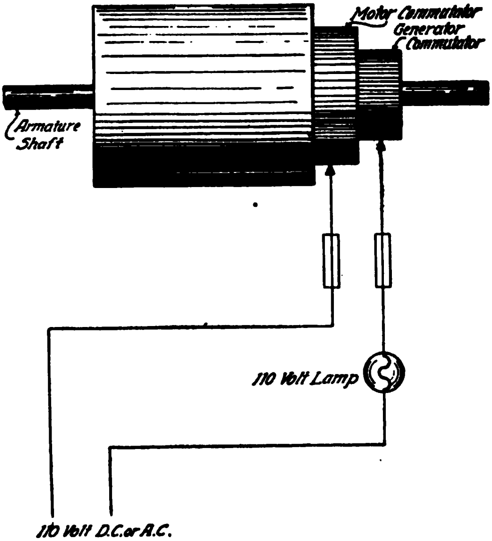


Fig. 265. Diagram for Locating Short-Circuits between Motor and Generator Armature Coils

naturally only applicable to single-unit machines having two independent windings on the same armature core, as in the case of the Delco, the type in question.

(d) *Open- or Short-Circuited Generator Armature Coils.* When testing for open- or short-circuited generator armature coils, the generator brushes should be left in contact with the commutator, but the storage battery should be disconnected from the system, carefully taping the loose battery terminals before proceeding. Then disconnect the shunt field from the brushes and tape these terminals so that they do not accidentally come in contact with the frame or other parts of the unit. Connect up a dry cell and the portable ammeter, using the 30-ampere shunt, as shown in Fig. 266. Turn the armature over slowly by hand. If the commutator is clean and bright and the brushes are making good contact with it, a very noticeable change in the ammeter reading will indicate an open- or a short-circuited armature coil. To determine whether the coil is open- or short-circuited, the following tests should be made:

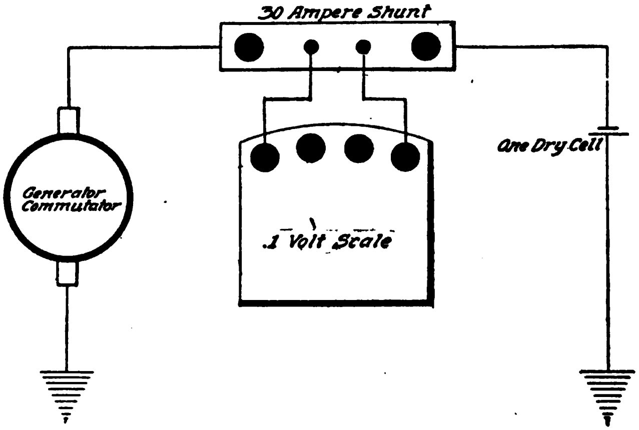


Fig. 266. Diagram for Testing Open- or Short-Circuited Generator Armature Coil with Ammeter

(1) *Open-Circuited Coils.* Connect the brushes to the terminals of the dry cell so that a current of about 10 amperes is flowing through the brushes. The field should be entirely disconnected and its terminals either taped or held out of the way. Then, with a special pair of points connected to the voltmeter,

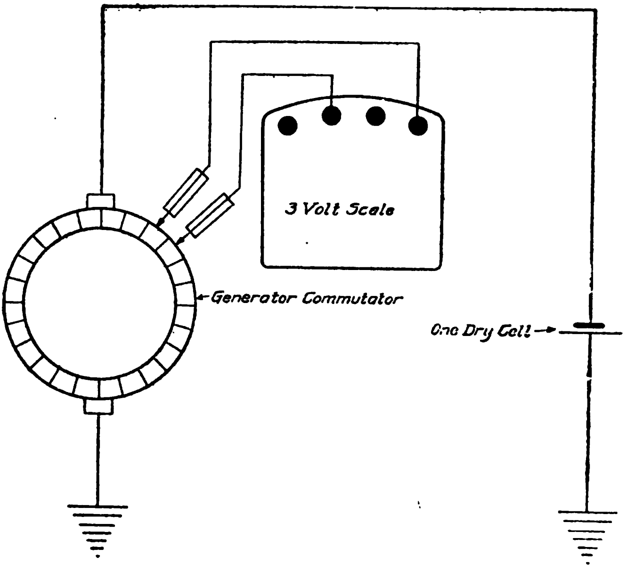


Fig. 267. Diagram of Set-Up when Coils Are Open-Circuited

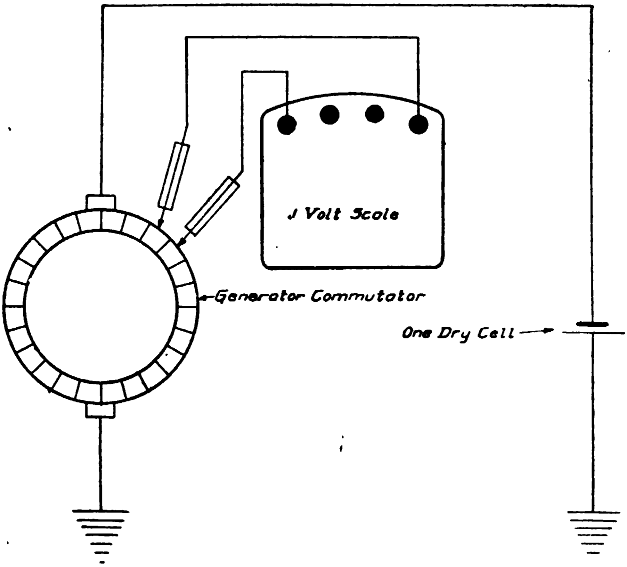


Fig. 268. Diagram of Set-Up when Coils Are Short-Circuited

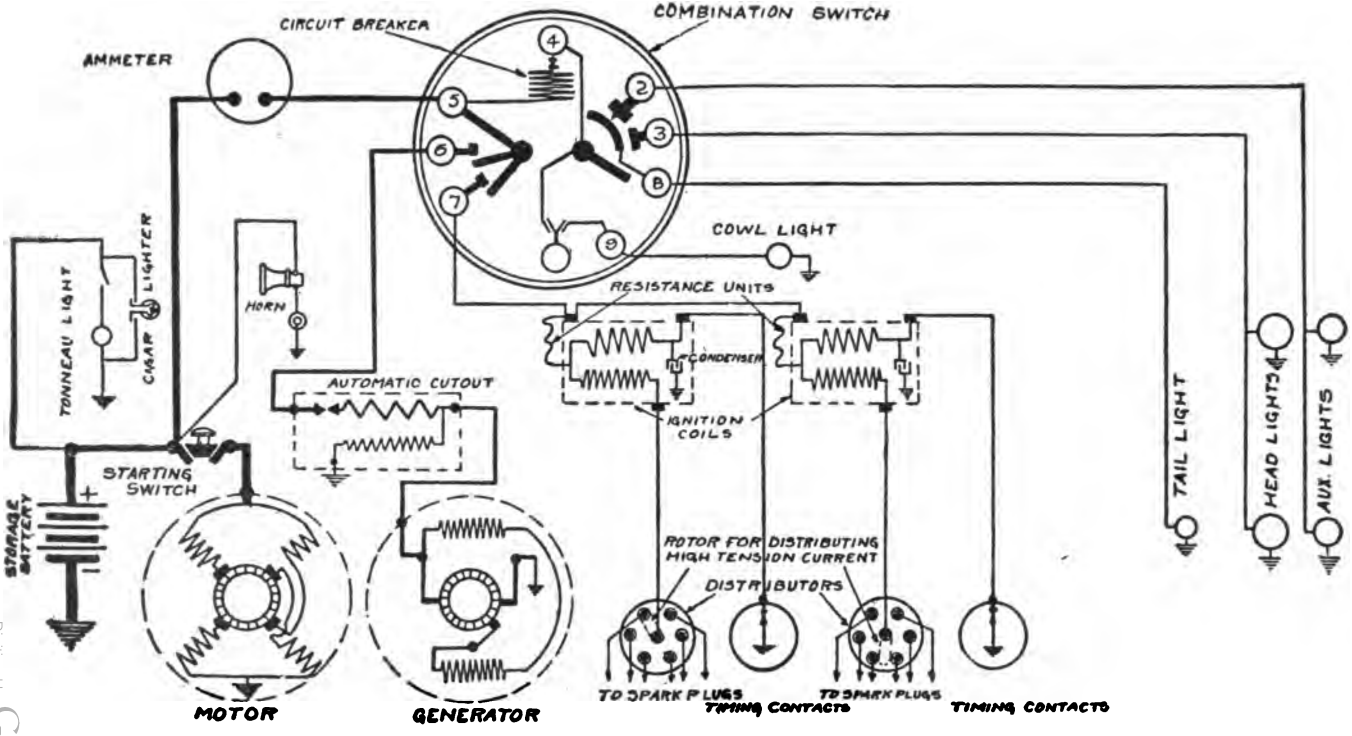
using the 3-volt scale, measure the voltage across each two adjacent commutator bars. If there is an open-circuited coil in the armature, the voltage reading will increase considerably, Fig. 267.

(2) *Short-Circuited Coils.* If there are no open-circuited coils and the preceding tests indicate that there is trouble with the armature, it should be tested for short-circuited coils. This should be done only after the preceding tests have been made, as an open-circuited coil might cause the .1-volt scale of the voltmeter to burn out if this test were made first. The armature is connected as indicated in(1) above, but for this test the .1 -volt scale instead of the 3-volt scale of the voltmeter is used, Fig. 268. The voltage drop between adjacent commutator bars is then measured by slowly turning the commutator over by hand. The readings should be approximately the same. If any of them drop nearly to zero, it will indicate that one or more of the armature coils are short-circuited. In taking these readings, care must be observed to keep the points always on adjacent commutator bars and not allow them both to come on the same bar at any time; otherwise, the voltage drop may be sufficient to injure the voltmeter.

Should any of these tests indicate open- or short-circuited coils in the armature, it is advisable to send the armature to the manufacturer for repairs, or to install a new armature. Unless the fault is plainly visible, as where a coil-terminal connection at the commutator bar has broken or become short-circuited, the average establishment will find the repair entirely beyond its facilities to make, so that time and expense will be saved by promptly referring it to the factory. Special equipment and skill in the handling of such repairs are indispensable and are beyond the province of the garage man.

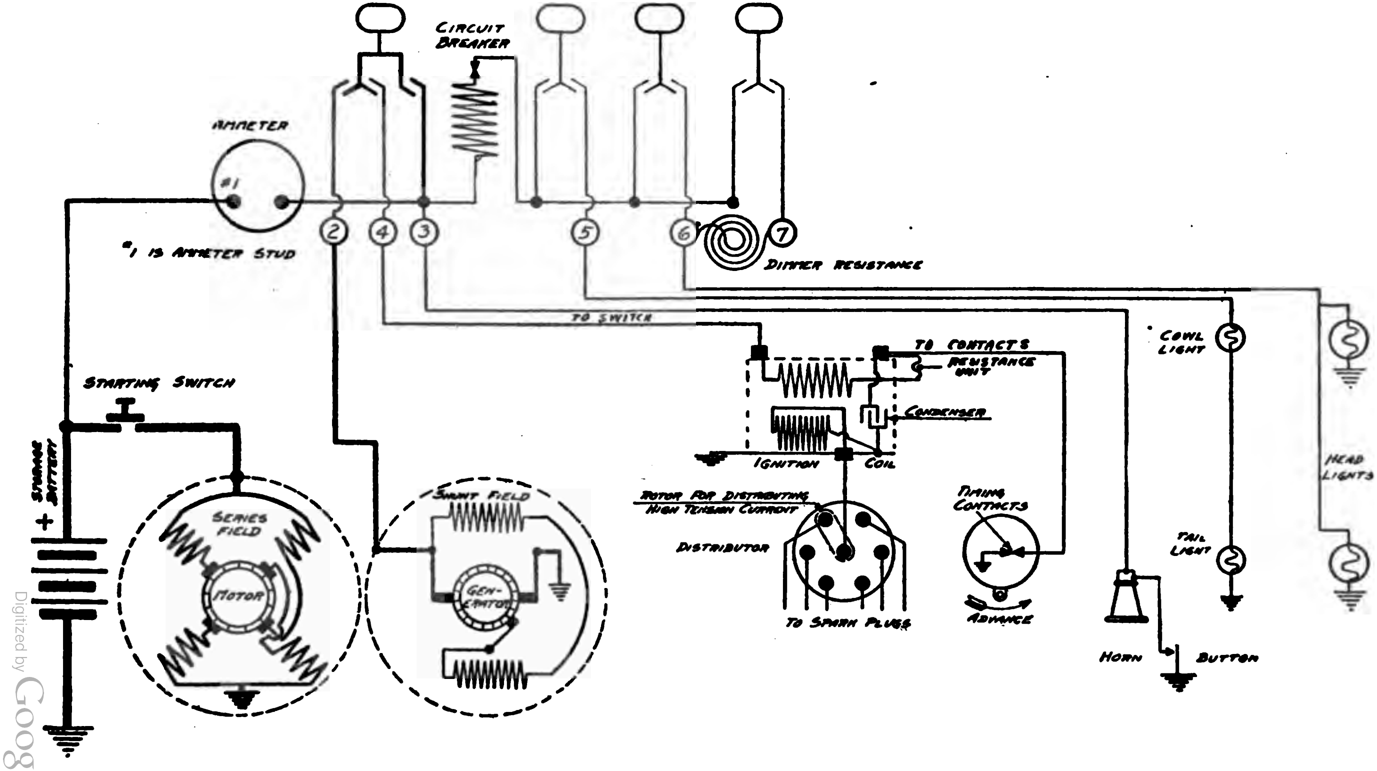
Testing Field Coils. The tests of field coils are simpler than those of the armature, and they apply in large measure to practically any system.

Open-Circuits in Fields. To test for open-circuits in fields, the test set is the only apparatus required, and the points should be placed as shown in Fig. 269. By placing one point on each terminal of the particular winding to be tested, failure of the lamp to light



87	**Generator**	2123	**Ignition Coil (2)**	6064	**Ammeter**	86	**Motor**
5156	**Distributor**	1082	**Combination Switch**			1966	**Motor Switch**

Delco Starting and Lighting Installation on the Pathfinder, 1917 Twelve-Cylinder Model



103 **Generator** **2139** **Ignition Coil** **104** **Motor**
1067 **Combination Switch** **1965** **Motor Switch**

Delco Starting and Lighting Installation on the Pilot 1917 Cars, Model 6-45 will indicate that the coil is open-circuited, as the wire of the coil will afford a path for the current, unless broken. The fact that the lamp may not light to full brilliance in some of these coil tests is no indication of trouble, as the difference is simply due to the additional resistance represented by the coil itself. In case an open-circuited coil is found, the only remedy is to return it to the manufacturer for repair or replacement.

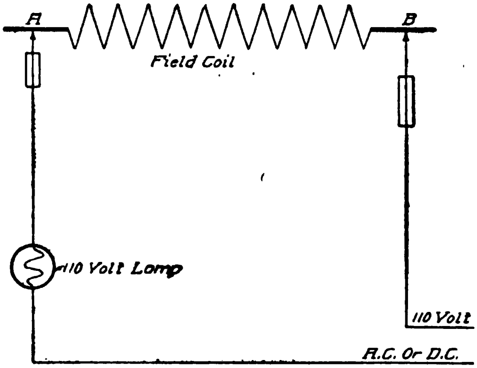


Fig. 269. Diagram for Locating Open Circuits in Field Coils with Lamp-Testing Set

Grounded Fields. To test for grounds in the field windings, place one test point on the frame of the machine and the other on a terminal of the field coil. Before doing this, however, all intentional ground connections made by the terminals should be removed. These can be located by referring to the winding diagram. If the lamp lights, it will indicate a ground. The manner of applying the test points is shown in Fig. 270.

Short-Circuits between Windings. To test for short-circuits between windings not normally connected, as for example the shunt and series winding of a field coil, place one test point on the terminal of one winding and the other test point on the terminal of the other field winding, as shown in Fig. 271. If the lamp lights, it will indicate a short-circuit between the windings. The field coils can also be tested with a voltmeter, the 30-volt scale being used in connection with a 6-volt storage battery for this purpose, Fig. 272. Detailed instructions for the use of the instrument are given in a previous section. As

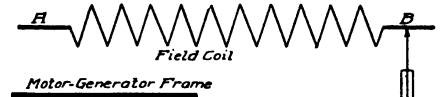


Fig. 270. Diagram for Locating Grounded Fields

all lighting generators have more than one winding on their fields, i.e., shunt and series windings (the latter termed "bucking coils" when reversed), these tests are equally applicable to all makes.

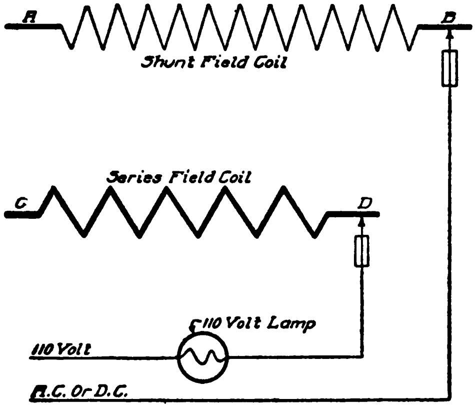


Fig. 271. Diagram for Testing Short-Circuits between Windings

Voltmeter Field Tests. The method of employing the voltmeter for making field tests, shown in Figs. 272 and 273, is as follows:

To. test for an open-circuited field, connect up as shown in Fig. 272. The positive terminal of the voltmeter is connected to the positive terminal of the battery. An insulated copper wire of convenient length, with the insulation stripped off for about one inch at each end, is then attached to the terminal of the voltmeter marked "30 volts", and a similar wire is attached to the negative terminal of the battery. The free ends of these wires are then used in the same manner as the points of the test set, except that the voltmeter reading is the indication sought instead of the lighting of a lamp. Before making the test, touch the free ends of the wires together. This reading will be the total voltage of the storage battery, and it should be kept in mind when making the tests.

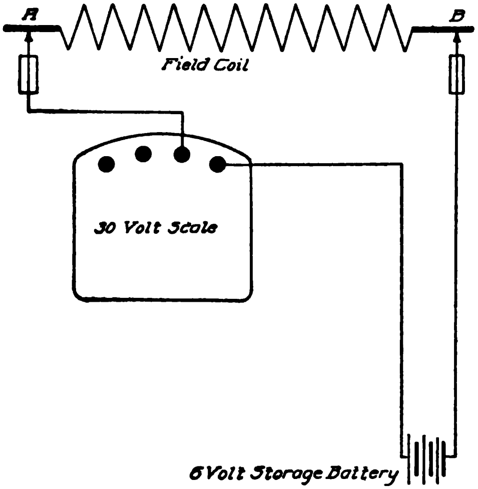


Fig. 272. Voltmeter Test Diagram for Open-Circuited Field

If, instead of touching the free ends of the wire together, they are placed on the terminals of a high resistance, the voltmeter reading will naturally be much less. In other words, the value of the voltmeter reading will always depend upon the amount of resistance offered by the coil or other circuit that is being tested. When there is no circuit, as with the free ends held apart in the hands, there will be no indication on the voltmeter scale. An open-circuited coil will accordingly be indicated by a zero reading of the voltmeter when the two free ends, or points, are placed upon the terminals of the coil, Fig. 272. If, on the other hand, the voltmeter reading is nearly half of that of the battery voltage, the coil is in good condition. This test corresponds to that with the lamp-testing set using the 110-volt current, illustrated in Fig. 269. It is a method which also permits one coil to be checked against another of the same kind, as the readings given by the two coils should be approximately the same. Where neither a 110-volt current nor a portable voltmeter are available, these tests may be carried out with the aid of a 6-volt bulb in connection with the storage battery, as shown for the voltmeter tests. In this case, the lamp will light brightly when the free ends of the wires are brought together, but it will dim in proportion to the amount of extra resistance added to the circuit, as represented by the coil under test. While not so accurate as the tests with the voltmeter, comparative

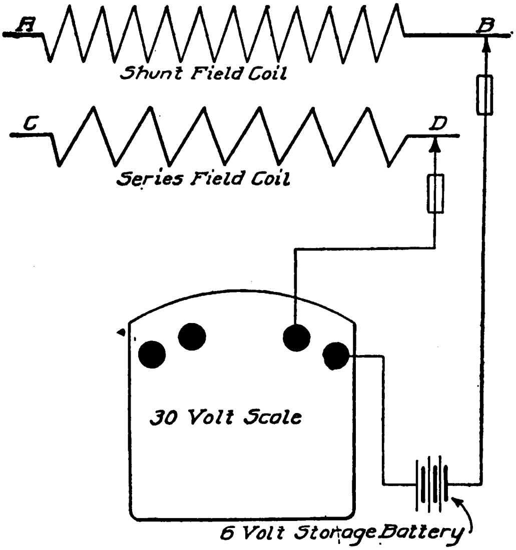


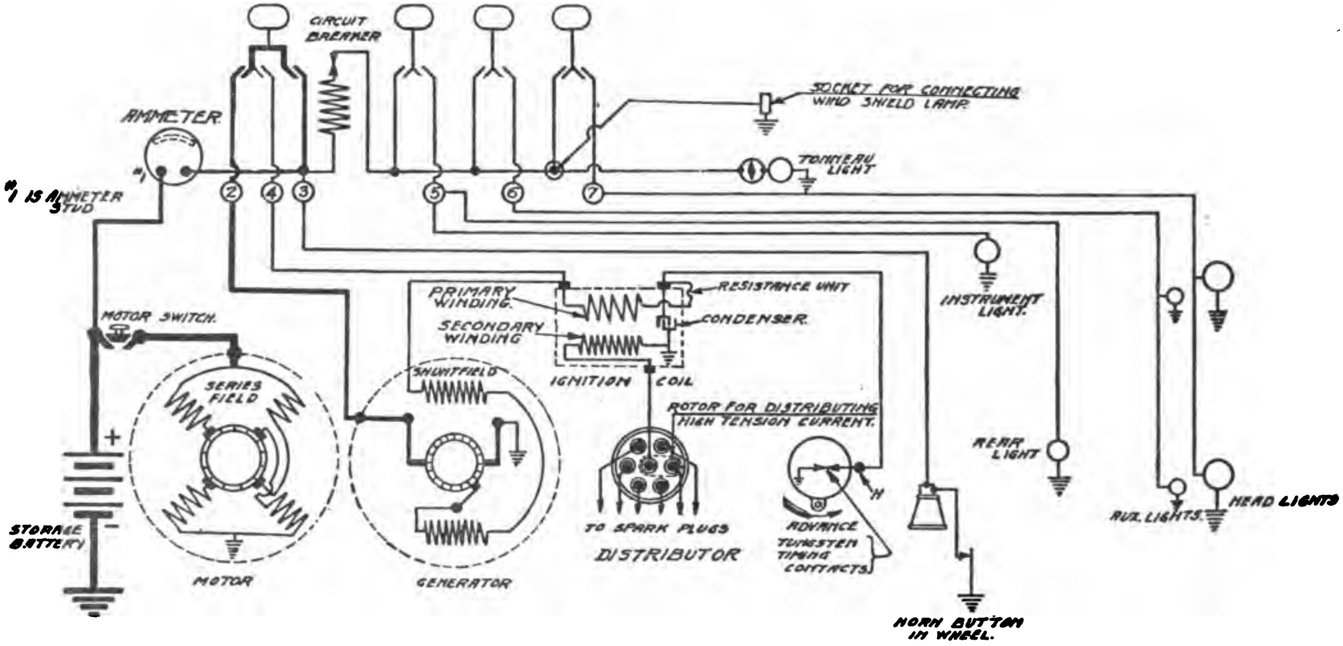
Fig. 273. Voltmeter Test Diagram for Short-Circuit between Coils

tests are also possible with the low-voltage lamp, a very perceptible difference in the lighting of the lamp indicating a greatly increased resistance. When using current from a storage battery for testing, care must be taken to have the points of the test set, or ends of the wire, clean and bright, and to make good, firm contact. If necessary, places on the machine at which the test points are to be applied should first be scraped or filed clean, otherwise, additional resistance will be inserted by the poor contact at the points, as for example, where the latter are applied to a painted surface.

To test for grounds in a field, after having removed all ground connections, as mentioned in a previous paragraph, place one end, or point, on a terminal of the field coil and the other on the frame of the machine. The method of making the test is identical with that shown in Fig. 270, except for the substitution of the voltmeter for the 110-volt light circuit. If the coil is free from grounds, the voltmeter needle will remain at zero; in case, there is a ground, there will be an indication on the instrument and the worse the ground the greater the value of this reading will be. This test corresponds to that illustrated in Fig. 264.

Short-Circuits between Coils. The test for short-circuits between coils is similar to that shown in Fig. 265 and naturally applies to all lighting generators where the two windings of the fields are concerned. Place one end, or point, on the terminal of one winding and the other end on the terminal of the other winding, as shown in Fig. 273. If there is no connection between the coils, as should be the case, the voltmeter needle will remain stationary. Any movement of the voltmeter needle indicates a short-circuit and the greater the value of the reading, the more complete is the short-circuit between the two coils.

In order to make these tests without removing the machine from the car, first, disconnect the storage battery and tape the disconnected terminals; then, insulate all the brushes by placing pieces of cardboard between them and the commutators. Disconnect all wires leading to generator terminals, and, likewise, all wires leading to field-coil terminals. By referring to the circuit and wiring diagrams for the particular car under consideration, all these leads can readily be identified, and after disconnecting them, the field coils of the machine can be tested. When the tests indicate that the field coils

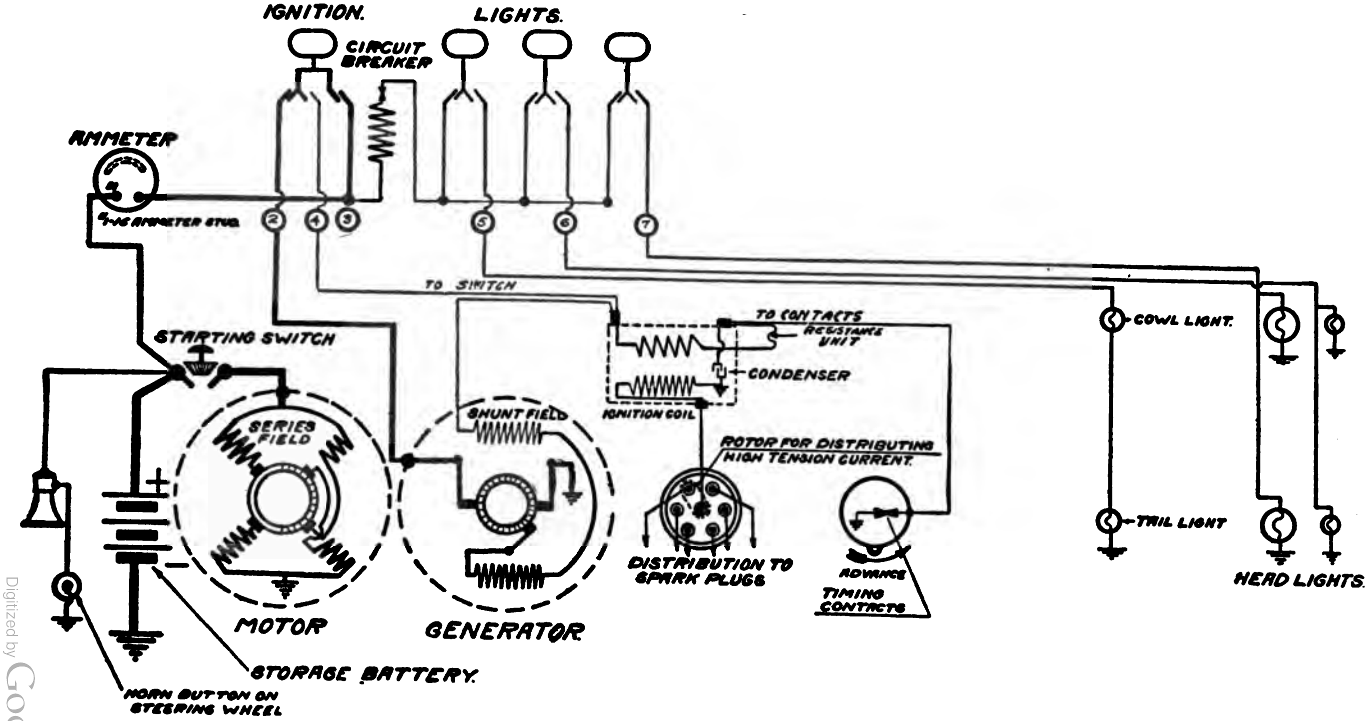


109 or 118 Generator
1086 Combination Switch

2145 Ignition Coil

110 Motor
1965 Motor Switch

Delco Starting and Lighting Installation on the Premier 1917 Cars, Model 6-B



105 Generator
1061 Combination Switch
1964 Starting Switch
2139 Ignition Coil
106 Starting Motor

Delco Starting and Lighting Installation on the Stephens, 1917 Model are not in perfect condition, it will usually be found advisable to remove the field coils from the machine and send them to the manufacturer for repair or replacement, for unless the fault is plainly apparent, which will seldom be the case, the repair will usually be found to be beyond the average garage facilities.

DISCO SYSTEM

Twelve-Volt; Single-Unit

Dynamotor. The dynamotor is bipolar with both windings connected to the same commutator.

Regulation. Constant current-control regulation by means of a vibrating regulator is employed. (See description of the Ward-Leonard regulator, Fig. 149, Part IV.)

Operating Devices. *Battery Cut-Out.* The cut-out is of the conventional type, combined with the current-control regulator.

Switch. The switch is the spring-controlled type which is only closed for starting.

Six-Volt; Two-Unit

Units. Both the generator and the starting motor are of the bipolar type, the motor being designed to operate through a Bendix drive.

Instructions. As both types of the system are characterized by standard features throughout, instructions given in connection with other systems apply here.

DYNETO SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. *Non-Stalling Feature.* Both windings are connected to the same commutator. No battery cut-out is employed, control being by means of a single-pole knife-blade switch, which is closed for starting and left closed as long as the engine is running. This switch also controls the ignition circuit. Upon closing the switch, the dynamotor acts as a starter and turns the engine over; as soon as the engine takes up its cycle and drives the dynamotor above a certain speed, the latter automatically assumes its functions as a generator and begins to charge the battery. Whenever the speed drops below that point, the dynamotor again acts as a motor to turn the engine over, this characteristic being termed the "non-stalling" feature of the system. Provided the battery is sufficiently charged, the dynamotor will always act as a starter (the switch being closed) whenever the engine is inadvertently stalled or its speed drops below the generating point of the machine.

Instructions. The switch must never be left closed with the engine stopped, and when the car is stopped, the engine must not be allowed to idle at a very low speed, as in either case the battery will be run down. Instructions for lack of generator capacity the location of grounds or short-circuits, and the like, are the same as for other systems.

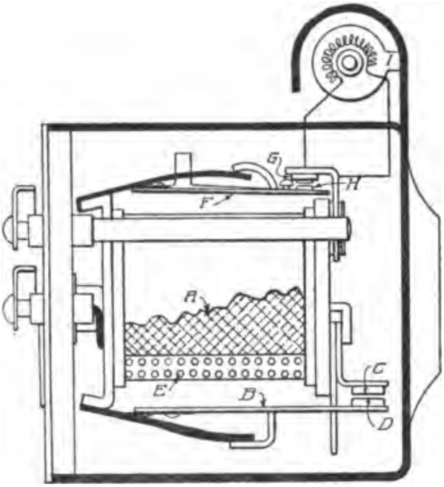
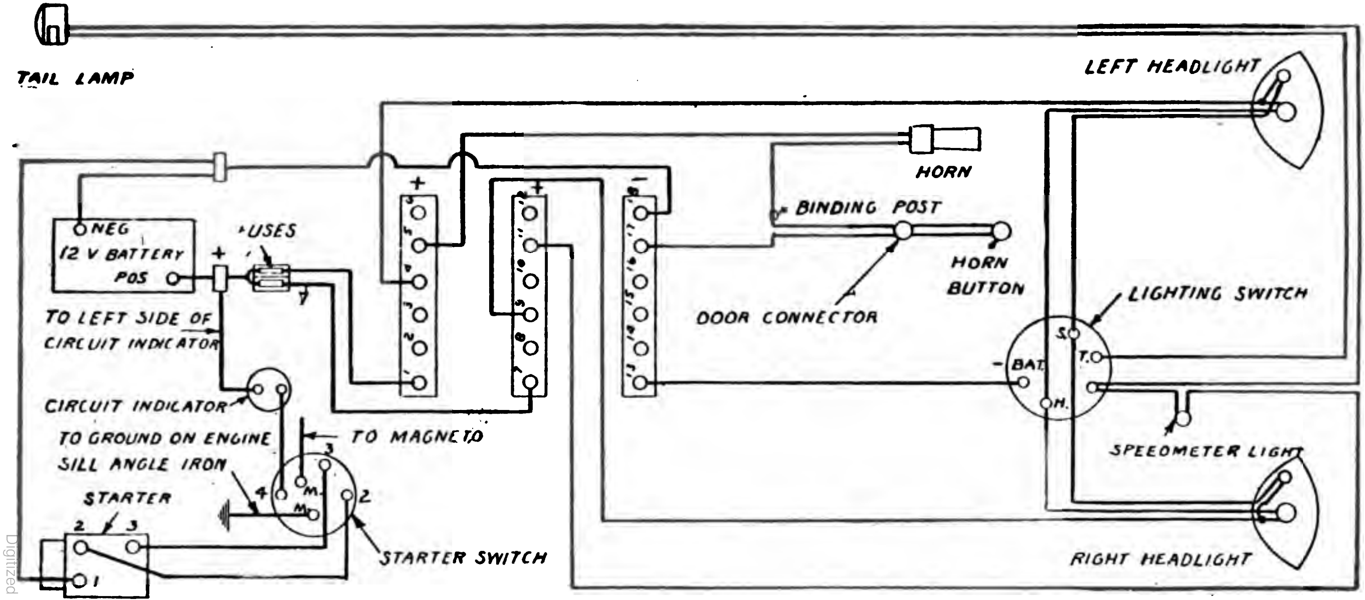


Fig. 274. Sectional View Showing Details of Dyneto Regulator-Cut-Out

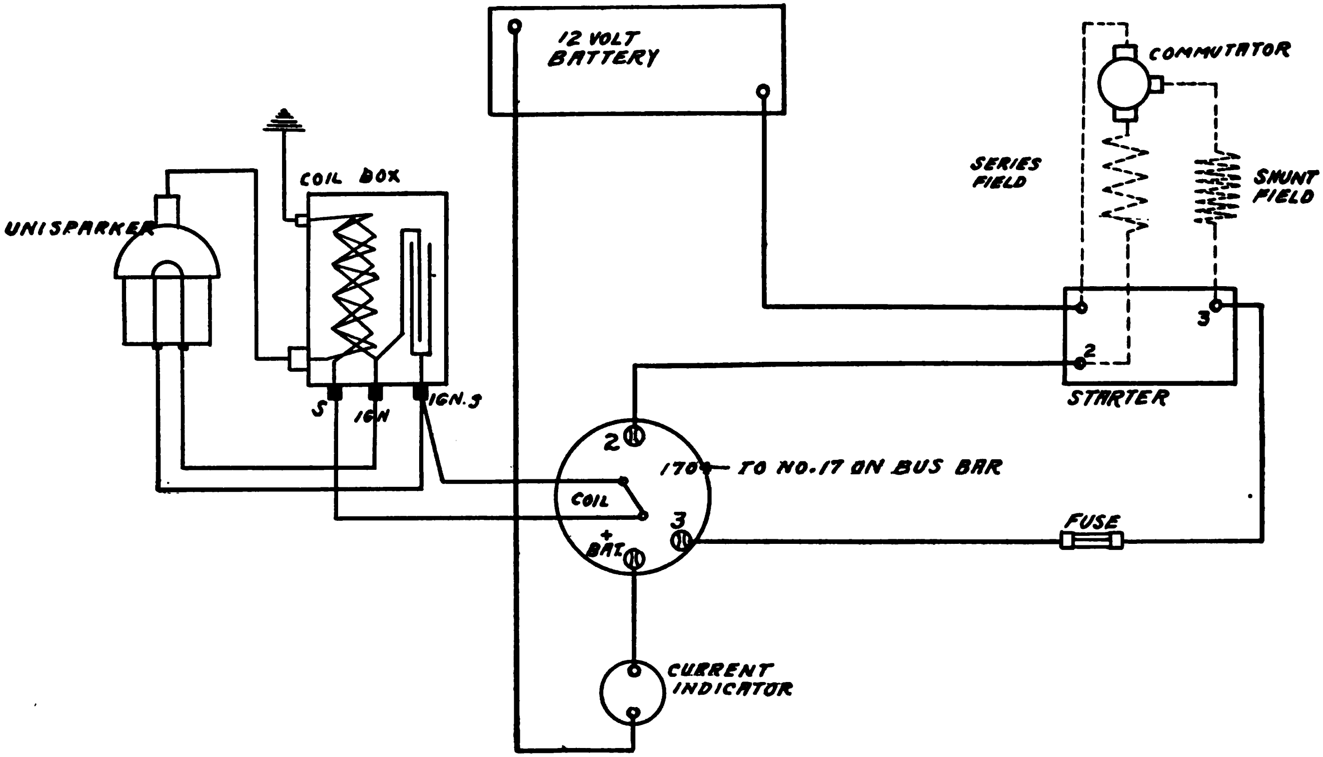
Six-Volt; Two-Unit

Generator. The generator is a standard shunt-wound machine of the four-pole type, having two wound, or salient poles, and two consequent poles. (See Fig. 219, Part IV.) It is ordinarily designed to be driven at one and one-half times engine speed, but, in common with other makes, machines wound for higher or lower speeds are furnished, according to the requirements of the engine on which it is mounted.

Regulation. Regulation is effected by means of a vibrating regulator, which is combined with the battery cut-out. This cuts in at a speed equivalent to 10 miles per hour, and the generator reaches its maximum normal output of 10 to 12 amperes between 12 and 15 miles per hour. The regulator does not become operative until the current flow increases to 10 to 12 amperes, at which point it is held regardless of the speed. The details of the combined regulator and cut-out are shown in Fig. 274, while all the connections are shown in the diagram, Fig. 275. As soon as the dynamo runs fast enough to cause it to generate, a portion of the current passes through the



Dyneto Starting and Lighting Installation on the Franklin, Series 8
Courtesy of Dyneto Electric Company, Syracuse, New York



Dyneto Starting and Lighting Installation on the Franklin, Series 9
Courtesy of Dyneto Electric Company, Syracuse, New York

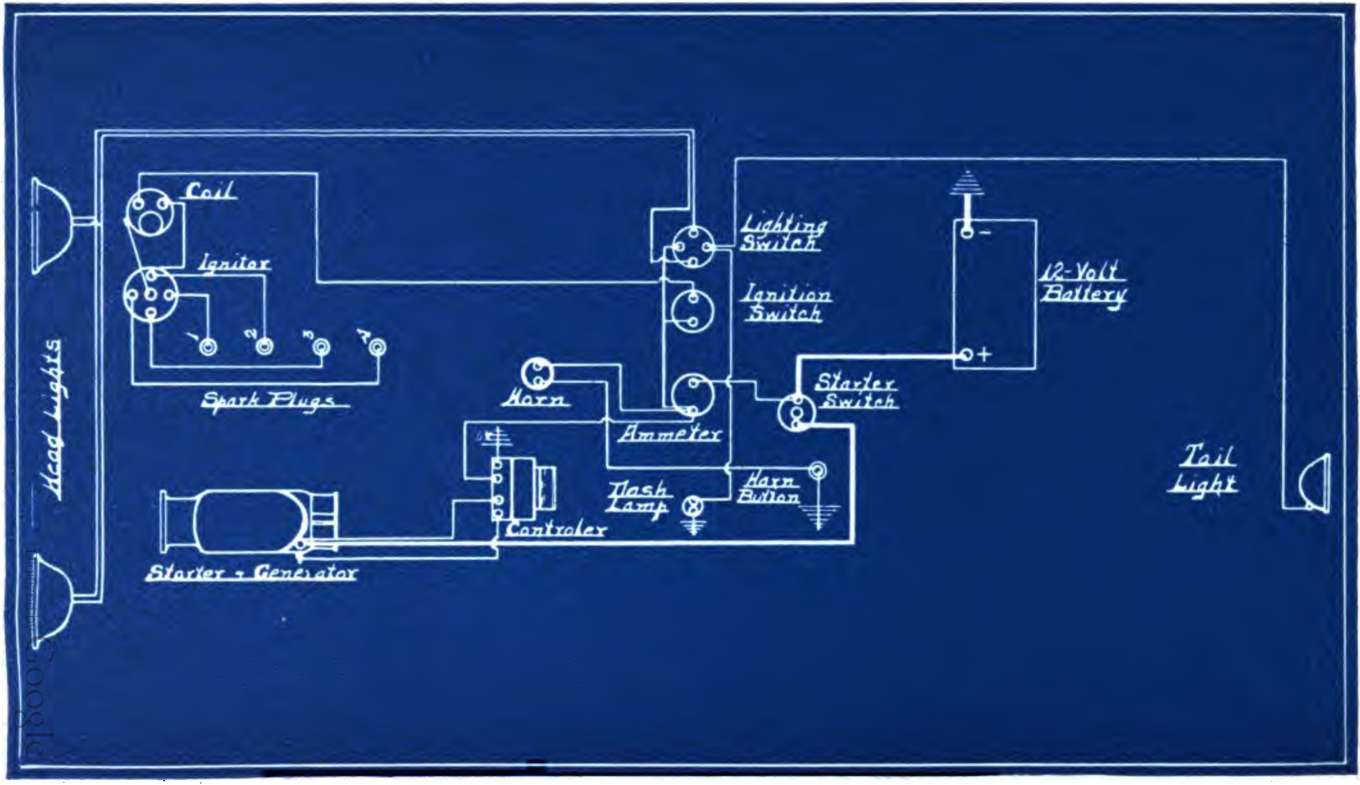


PLATE 34—DYNETO WIRING DIAGRAM FOR CROW-ELKHART 1916 CARS, MODEL 30

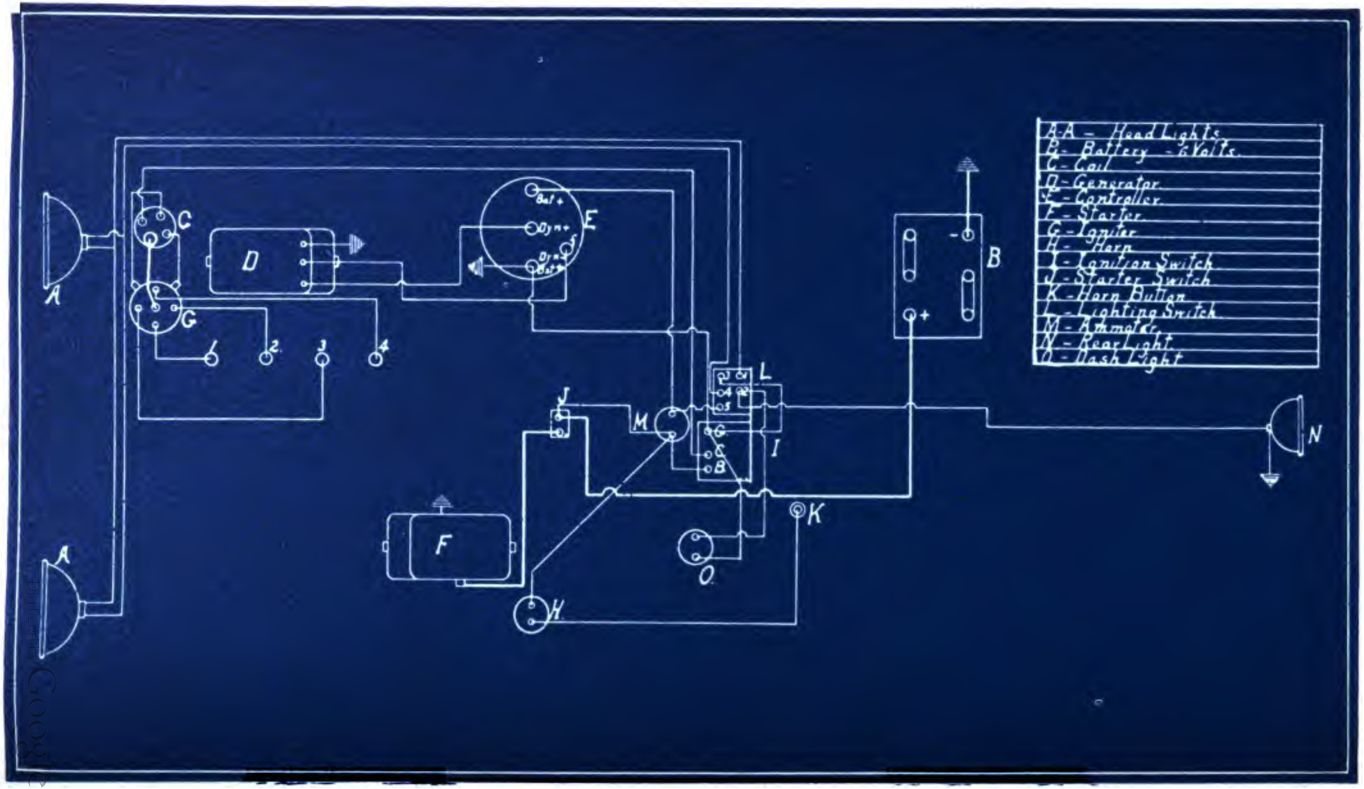


PLATE 36—DYNETO WIRING DIAGRAM FOR CROW-ELKHART 1916-17 CARS, MODEL C 28

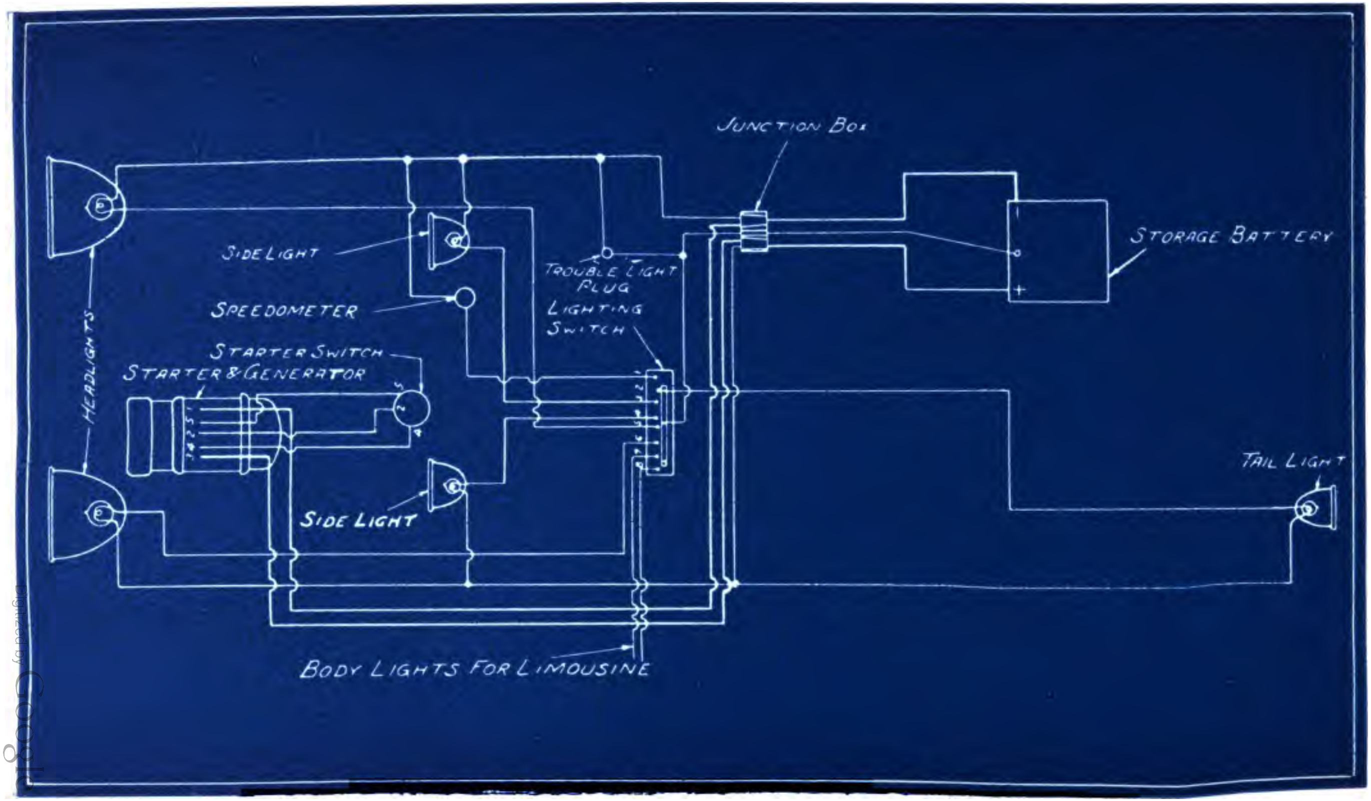


PLATE 36—NORTH EAST WIRING DIAGRAM FOR CUNNINGHAM 1912-14 CARS, MODEL "M"

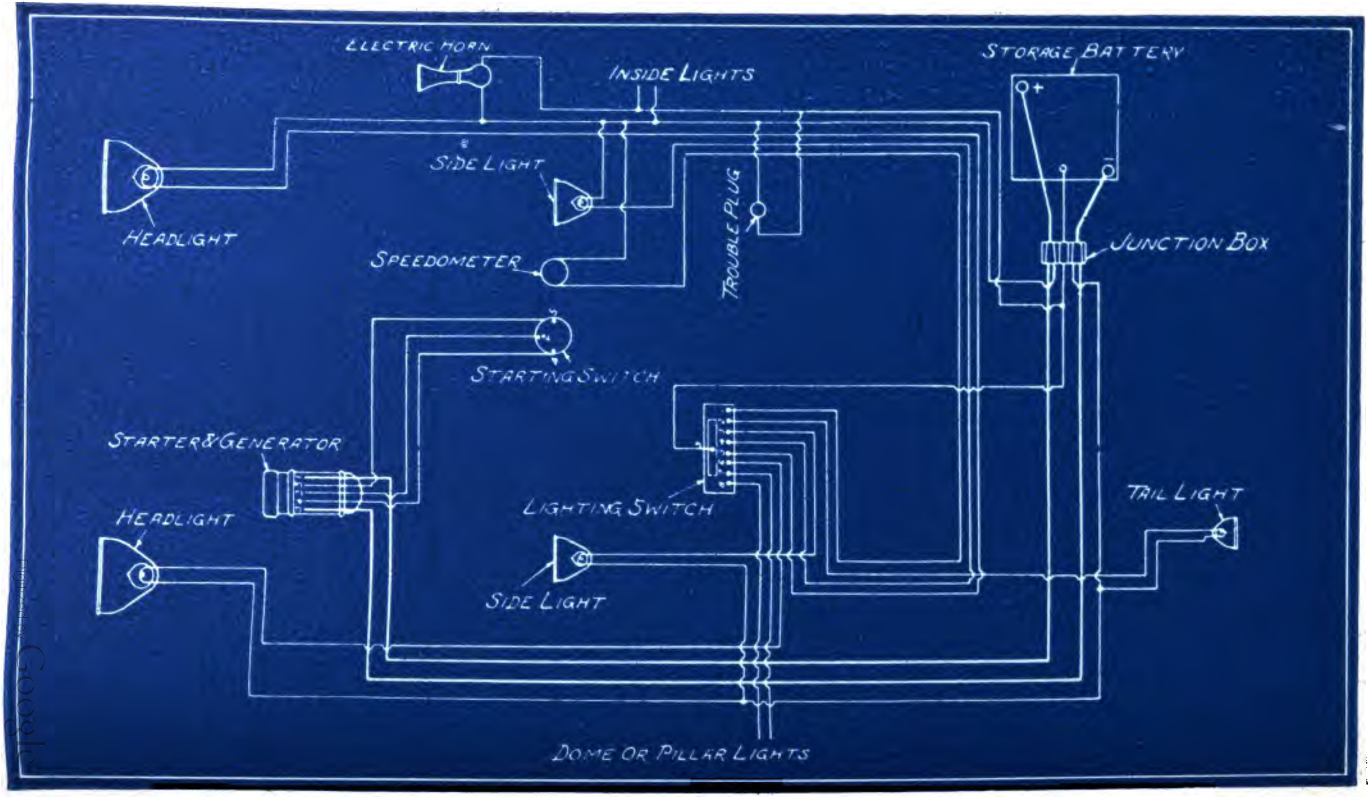


PLATE 87—NORTH EAST WIRING DIAGRAM FOR CUNNINGHAM HEARSES AND AMBULANCES, MODEL "M"

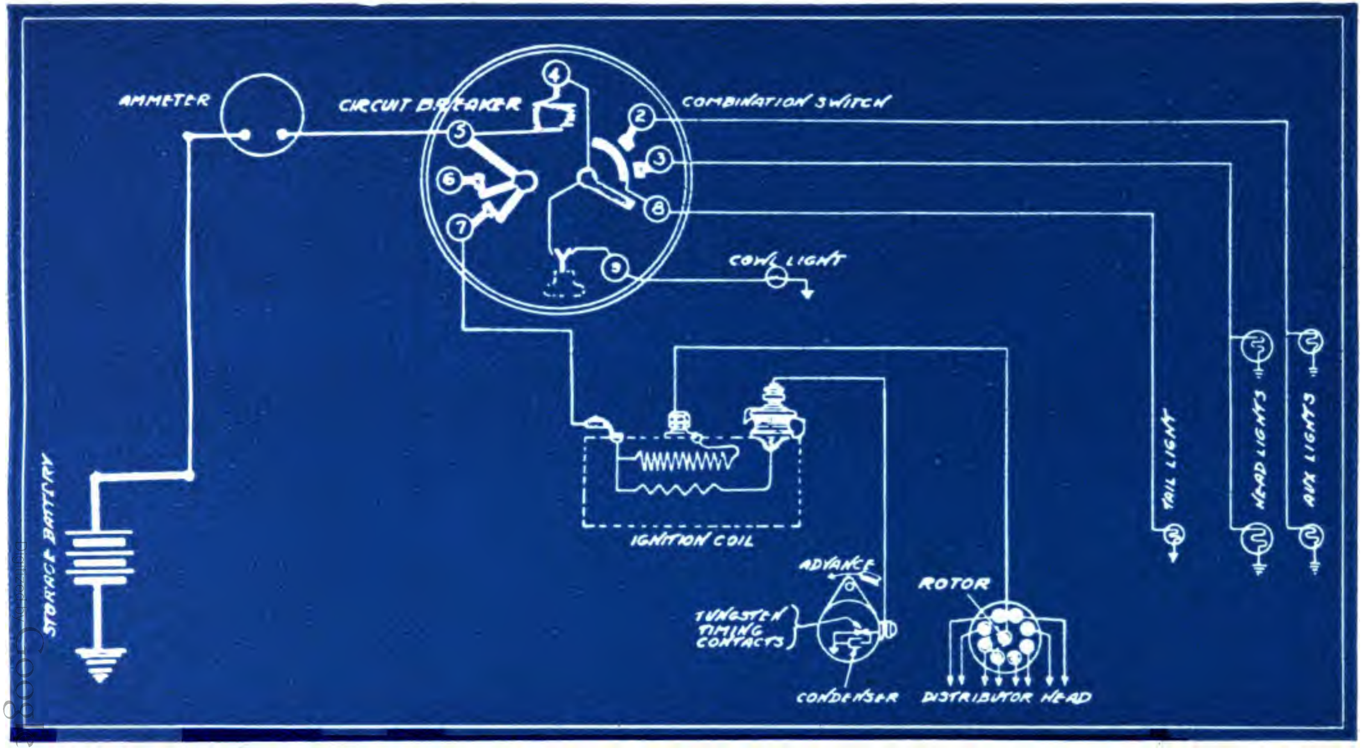


PLATE 38—DELCO STARTING AND LIGHTING WIRING DIAGRAM FOR CUNNINGHAM CAR, MODEL V-3

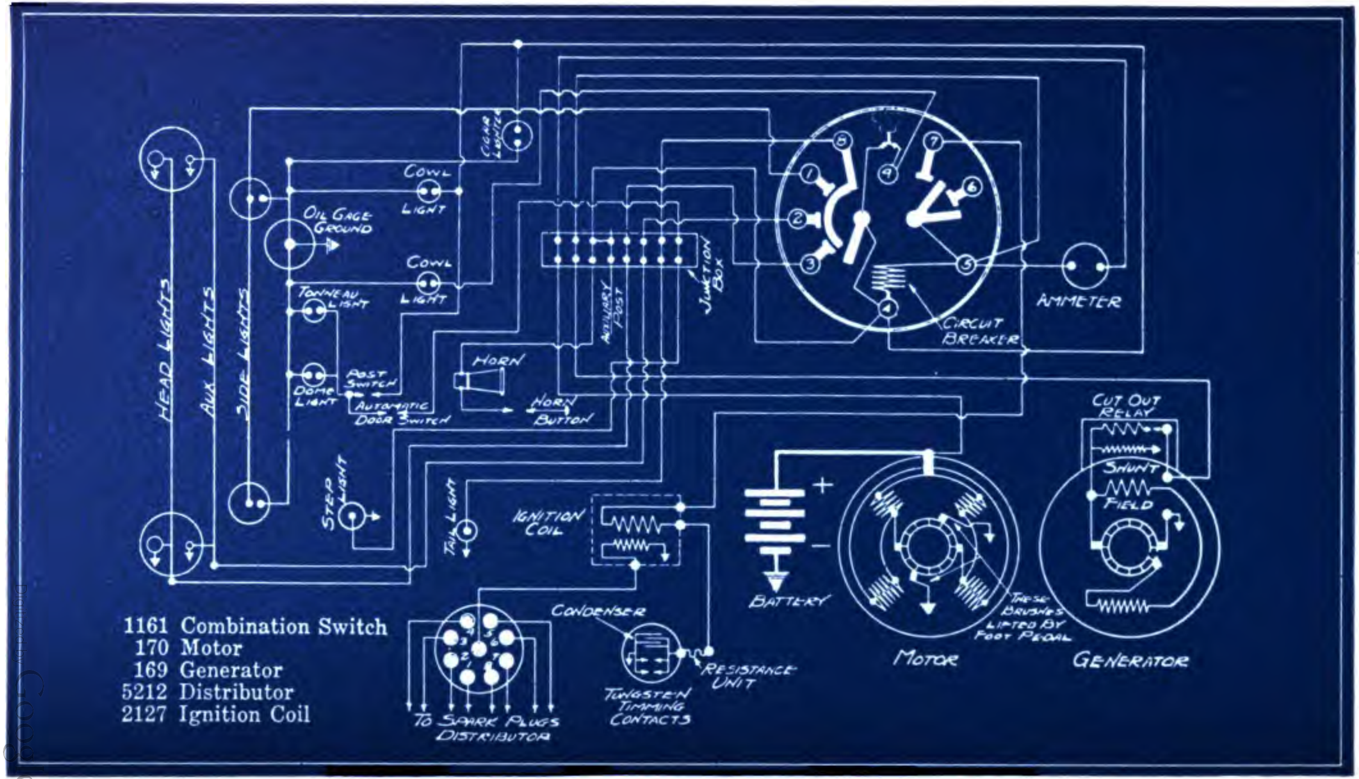


PLATE 38A—DELCO WIRING DIAGRAM FOR DANIELS 1920, MODEL D-19

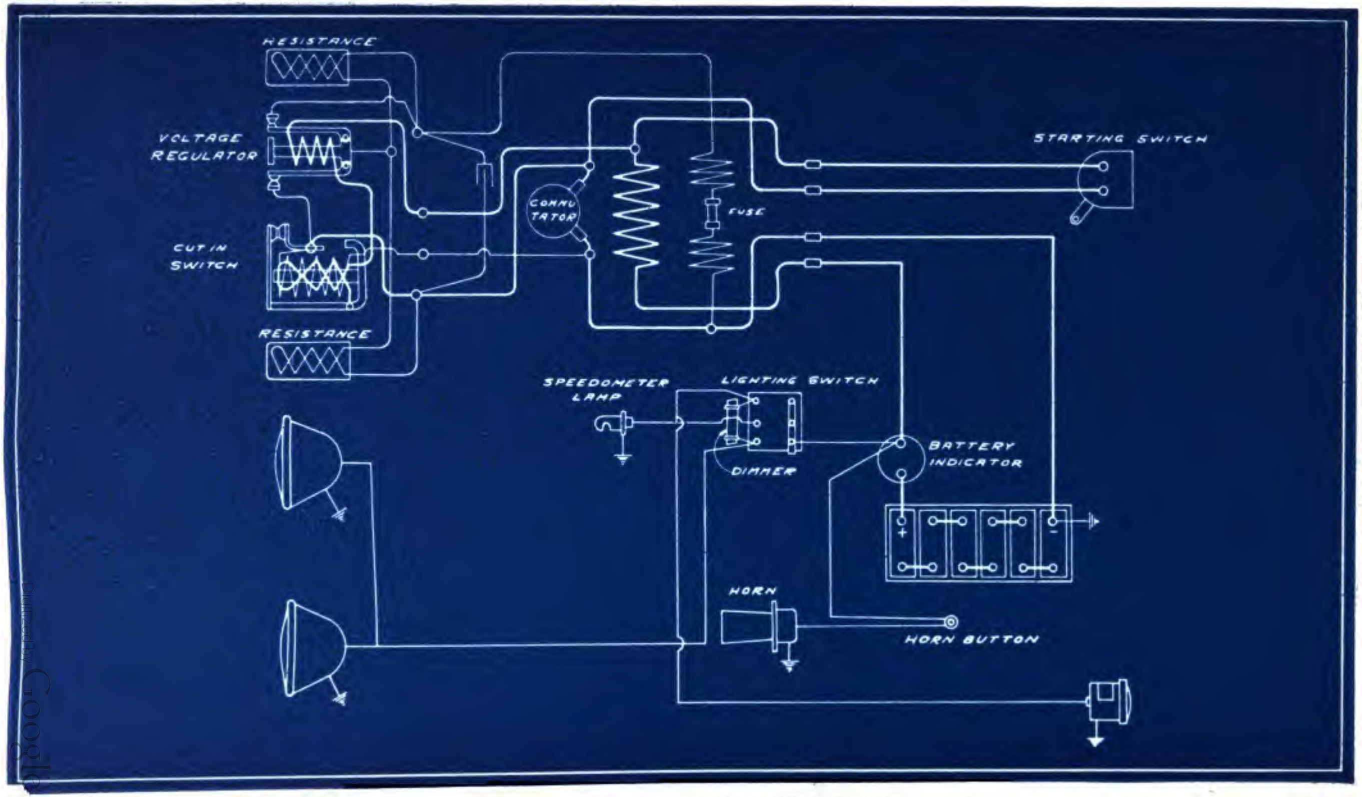


PLATE 39—NORTH EAST WIRING DIAGRAM FOR DODGE 1915 CARS

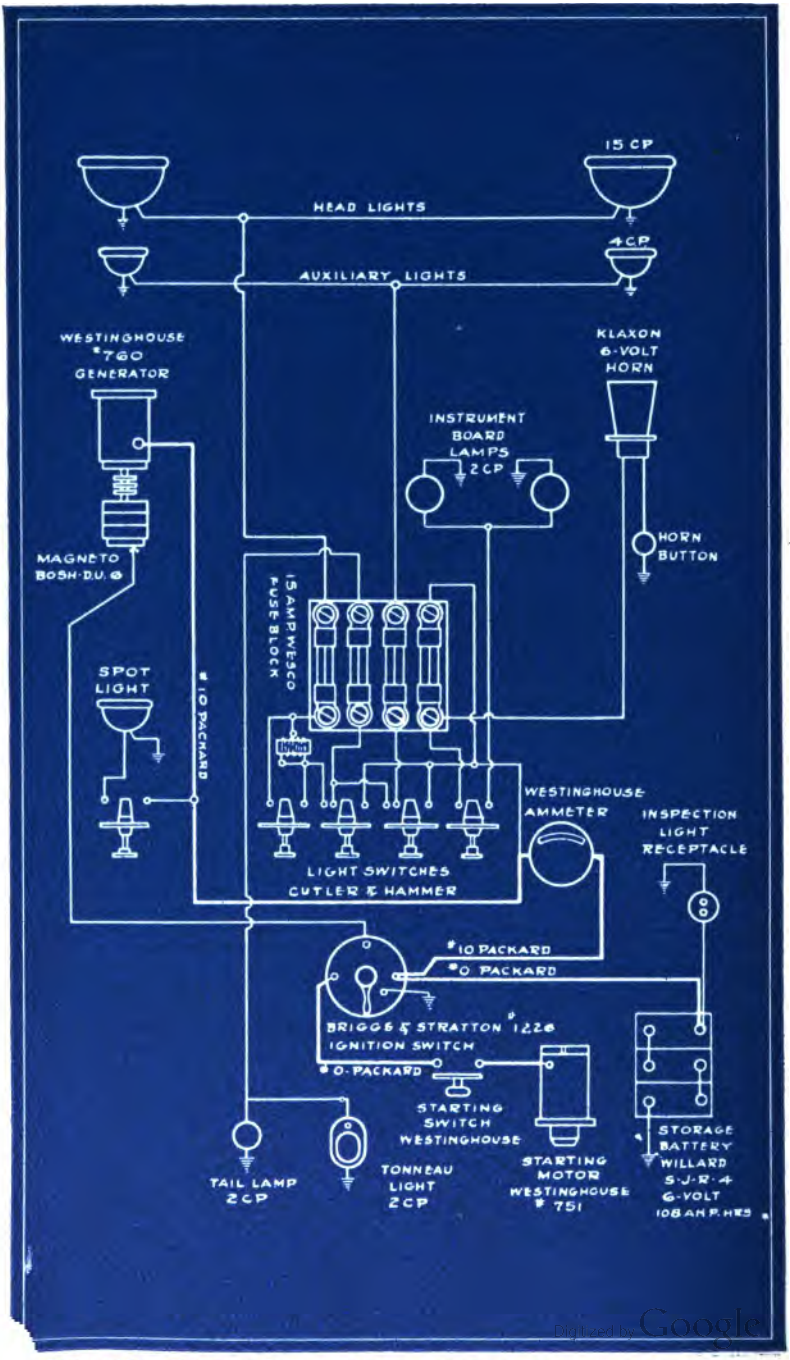

15 CP
HEAD LIGHTS
4 CP
AUXILIARY LIGHTS
WESTINGHOUSE #760 GENERATOR
KLAXON 6-VOLT HORN
INSTRUMENT BOARD LAMPS 2 CP
MAGNETO BOSH-D.U. 0
HORN BUTTON
15 AMP. WESCO FUSE BLOCK
SPOT LIGHT
# 10 PACKARD
WESTINGHOUSE AMMETER
INSPECTION LIGHT RECEPTACLE
LIGHT SWITCHES CUTLER & HAMMER
#10 PACKARD
#0 PACKARD
BRIGGS & STRATTON #1226 IGNITION SWITCH
#0-PACKARD
STARTING SWITCH WESTINGHOUSE
TAIL LAMP 2 CP
TONNEAU LIGHT 2 CP
STARTING MOTOR WESTINGHOUSE # 751
STORAGE BATTERY WILLARD S-J-R-4 6-VOLT 108 AMP. HRS

PLATE 39A—WESTINGHOUSE WIRING DIAGRAM FOR 1920 DORRIS, 6-80

winding *A* of the cut-out, Fig. 274. This is ordinarily known as the voltage winding and is of fine wire, so that very little current is required to energize the core and attract the armature *B*, which closes the contact points *C* and *D*. These points close the circuit through the coil *E*, which is of heavy wire and is known as the current coil. As the current in both coils is in the same direction, their exciting effect on the magnet core is cumulative, and the points are held together that much more firmly.

On the upper side of the magnet will be noted another armature *F* and a set of contact points *G* and *H*. This armature is subject to the same magnetic attraction, but the tension of its controlling spring is

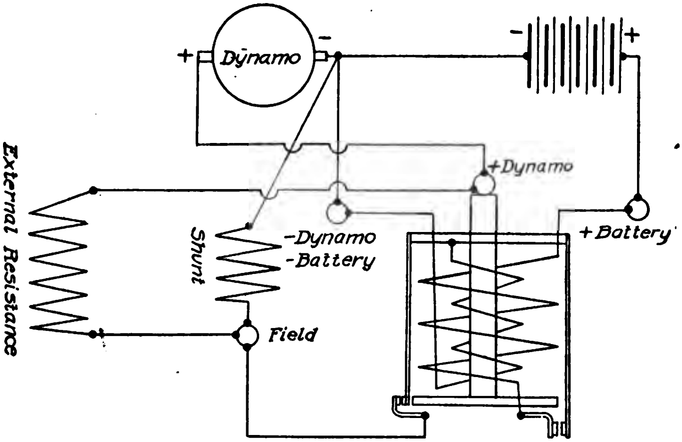


Fig. 275. Connections for Dyneto Regulator Cut-Out

such that the magnet is not strong enough to move it. This spring is so adjusted that any increase in the current beyond this point will cause armature *F* to be attracted, opening points *G* and *H*. These points are directly in the shunt-field circuit and a resistance coil *I* is connected across them, so that when the points are together, the resistance is cut out of the shunt-field circuit; when they separate, this resistance is added to that of the shunt field. With a charging rate of 10 to 12 amperes, the tendency toward any higher output with increased speed is checked by the almost imperceptible but very rapid vibration of the armature *F*, which cuts the resistance unit in and out of the circuit and causes a pulsating current to be sent through the field windings, thus keeping the output within the required limits. When the generator speed falls below the normal rate, the voltage drops correspondingly and the battery current overcomes that from the generator and reverses the current flow through the current coil *E*. This reverses the magnetic effect produced, *bucking* that caused by the generator current in the coil *A*, and, as the battery current is then superior to the latter, the magnetic effect of *A* is neutralized and the armature *B* is forced away, opening the contacts *C* and *D*.

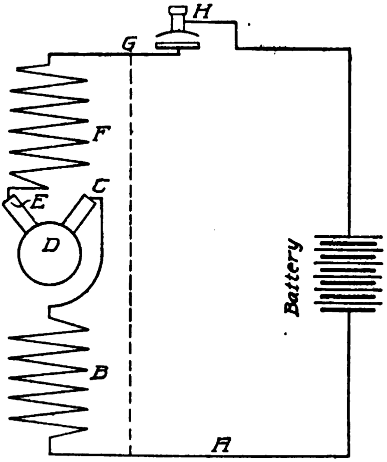


Fig. 276. Starting-Motor Circuit for Dyneto System

Starting Motor. This starting motor is of the standard series-wound type of the same characteristics of design as the generator. In Fig. 276 is shown the wiring diagram of the starting circuit and illustrates plainly the relation of the series fields *B* and *E* to the armature *D* and the brushes *E* and *C*. *H* is the starting switch and *A* and *G* are the cables of a two-wire starting system. Compare Fig. 276 with Fig. 277, which shows the shunt windings of the generator and their relation to the armature and battery. In Fig. 276 the dotted line from *G* to *A* illustrates a supposed short-circuit caused by chafing, or abrasion, of the insulation of the wires.

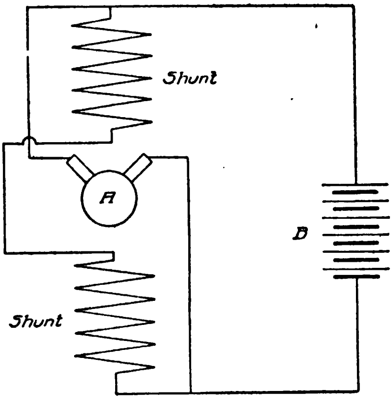


Fig. 277. Generator Circuit for Dyneto System

Wiring Diagrams. Either the single- or the two-wire system of wiring is employed, according to the car on which the system is installed. Fig. 279 shows the one-wire, or grounded, system, and Fig. 279 shows the two-wire system.

Instructions. In case of failure to start, the switch should always be released instantly and the battery tested to determine its condition of charge. If the battery is not run down, examine all connections and wiring, for, if a short-circuit exists as indicated by the dotted line at *G* in Fig. 272, no current can reach the motor. Failing to locate any short-circuit or ground in the system, open the name-plate cover

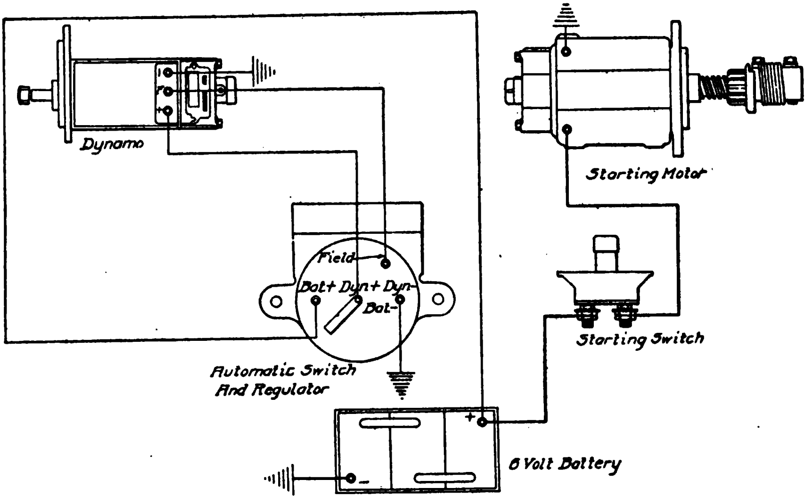


Fig. 278. Wiring Diagram for Dyneto One-Wire System

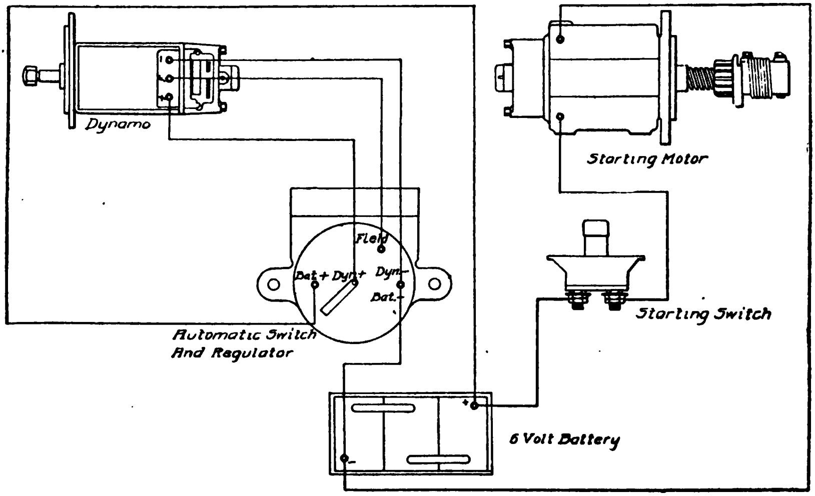


Fig. 279. Wiring Diagram for Dyneto Two-Wire System

on the starting motor and inspect the brushes. Lift each brush holder a trifle (if they are in proper condition, they should spring back when released) and press the brushes firmly against the commutator. (See Gray & Davis instructions for Spring Pressures on Starting Motors. These pressures are not the same on all makes, but this will give some idea of the high pressure necessary to make the contact required to handle the heavy currents used in the starting motor.) See that the commutator is clean and the brushes are making uniform contact all over their surfaces. Make sure that the two leads from the field coils to the brush holders are screwed down tightly.

When it is necessary to renew the brushes, remove the eight screws shown holding the end plate. Remove this commutator housing, or end plate, leaving the brush unit in place on the commutator. Remove only one brush at a time and replace it with a new one. Note bearing of brushes on commutator and sand-in to a true and uniform bearing over the entire surface of the end of each brush. When this has been done, carefully clean out all traces of carbon dust, using a rag wet with gasoline, if necessary; a small bellows may be used to advantage to blow this dust out dry, and will be more likely to get it out of the nooks and crannies then wiping. After the brushes have been sanded-in and the dust all cleaned out, see that both brush leads are tight and then replace the housing. New brushes should be necessary only after a year or two of service, sometimes longer; old brushes will operate just as efficiently as new ones, provided they have a bearing all over their surface and are held firmly against the commutator. A brush becomes too short for further use only when the spring can no longer hold it in good contact against the commutator. When ordering brushes, it must always be specified whether they are wanted for the generator or for the motor, and the type of machine, as stamped on the name plate, must be given. This applies equally to the brushes needed for any make of generator or starting motor, and no other brushes than those supplied by the maker for the machine in question should ever be used.

GRAY AND DAVIS SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. The bipolar generator is designed for drive by silent chain, as shown in Fig. 280, or when combined with ignition distributor from the pump shaft, Fig. 281.

Regulation. Earlier types, including the original lighting generator, were of the constant-speed type regulated by a governor and slipping clutch, which maintained the speed of the generator constant. The 1914 and subsequent models are controlled by a combination regulator cut-out, usually mounted directly on the generator itself. The regulator increases the resistance of the generator-field windings in proportion to the increase in speed, thus maintaining a steady output.

Starting Motor. The series-wound bipolar motor is made for either open or enclosed flywheel drive, according to the type of car. In Fig. 282 is shown the open flywheel type. The illustrations of both generator and motor show them with the side plate removed for inspection. The type of starting switch employed on later models is shown in Fig. 283. The rod passing through the switch leads to the pedal on the footboards for operating it.

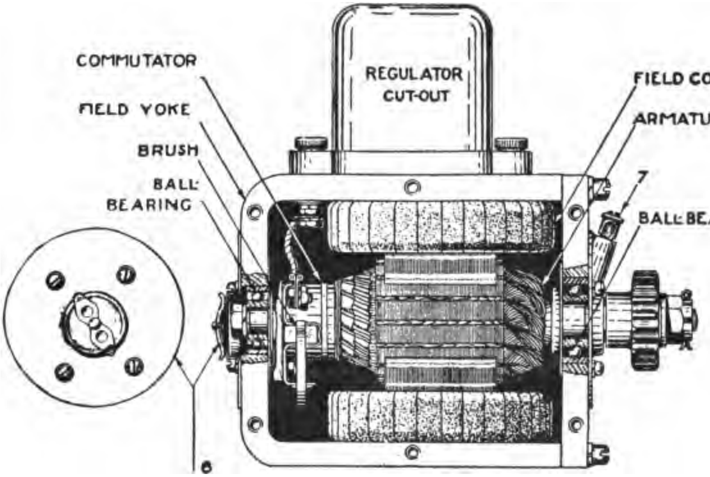


Fig. 280. Section of Gray & Davis Generator for Silent-Chain Drive

Instruments. Either an indicator showing whether the battery is charging, discharging, or is neutral, or an ammeter serving the same purpose, is supplied. The ammeter is provided with a graduated scale and its normal readings should be as follows: Standing, no lights on, *zero;* with lights on, *discharge* 5 to 7½ amperes. Car running 6 to 8 miles per hour, lights on, *discharge* same rate. Above 8 miles per hour, lights off, *charge* 5 to 9 amperes; above 10 miles per hour, lights on, *charge* 3½ to amperes. Under the last-named condition, the lights are being supplied directly by the generator and only the excess current is charging the battery. Whenever the generator output drops below a point where it is supplying

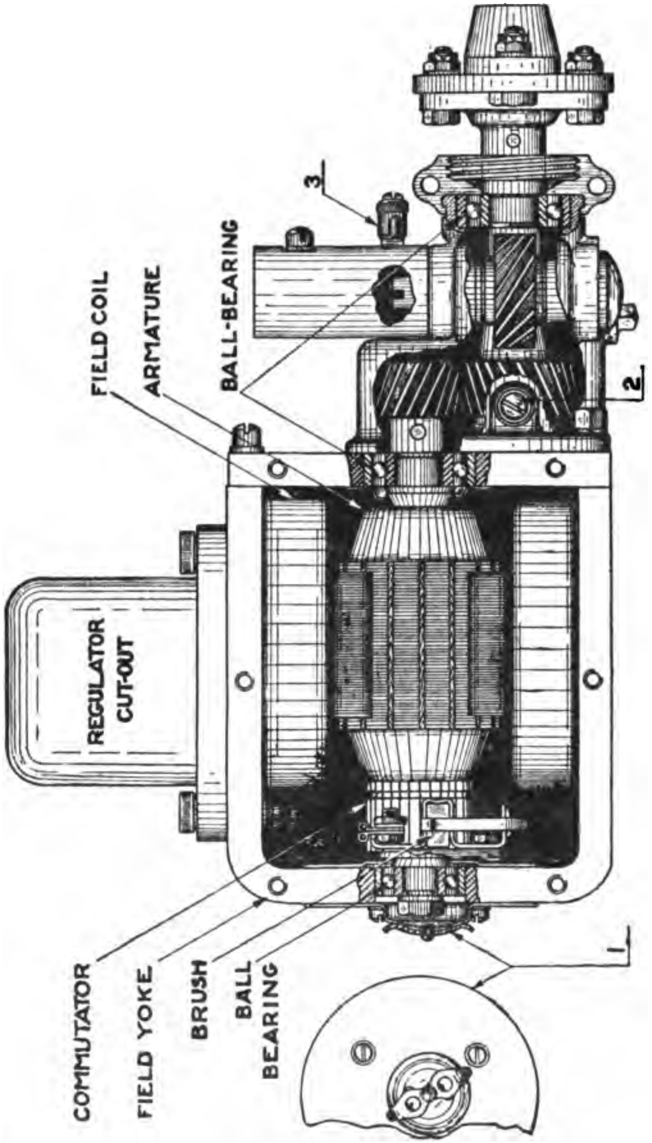


Fig. 281. Section of Gray & Davis Generator with Ignition Distributor Gearing (Shaft Drive)
Courtesy of Gray & Davis Company, Boston, Massachusetts

sufficient current to light all the lamps that are on, the battery supplies the balance. The battery is thus said to be *floated on the line.* It charges or discharges according to the current supply and the demand upon the latter.

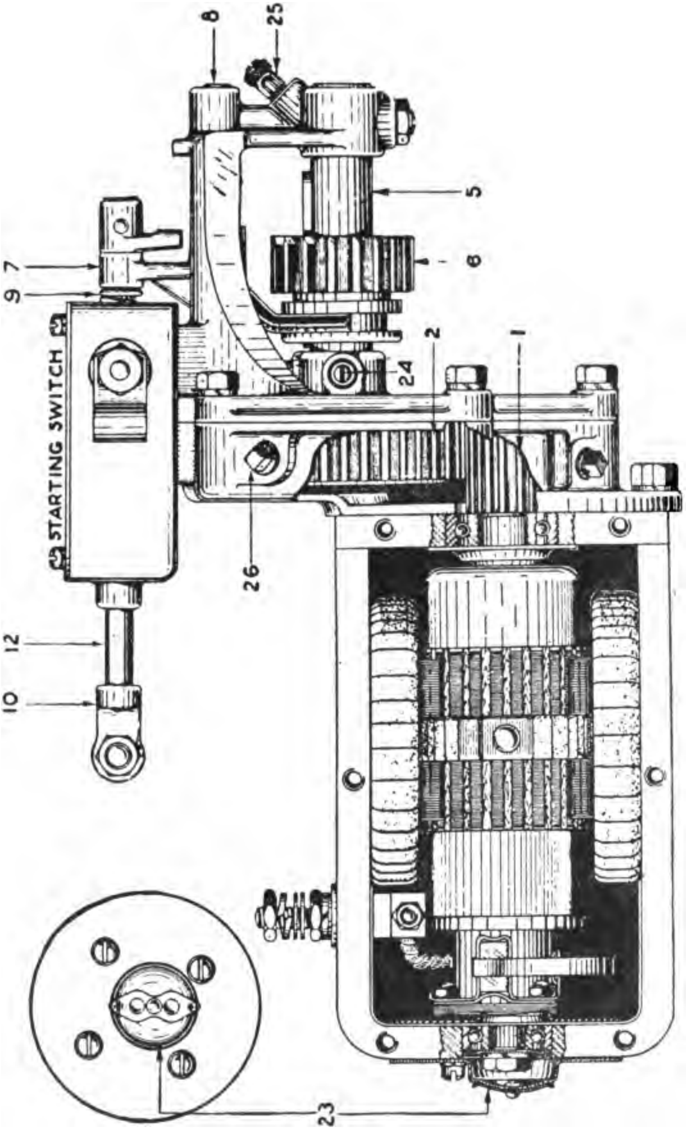


Fig. 282. Gray & Davis Starting Motor with Reduction Gearing for Open Flywheel. 1—Motor Pinion; 2—Intermediate Gear; 5—Intermediate Shaft; 6—Sliding Pinion; 7—Shifter Fork; 8—Shifter Rod; 10—Clevis; 12—Switch Rod; 23, 24, and 25—Oilers; 26—Oil Plug

Regulator Cut-Out. The regulator is of the constant-current type and on the Chandler, Metz, and Chalmers cars is set to allow the generator to produce a minimum of 8.5 amperes and a maximum of 11 amperes; on the Paige the minimum is the same, but the maximum is 12 amperes.

To Check for Adjustment. Insert the portable ammeter with the 30-ampere shunt in the circuit between the generator and the regulator and switch on all the lamps. Speed the engine up so that the generator is running above 1750 r.p.m. Open the upper set of points by inserting a match or using the finger, then adjust the lower set of points in accordance with the reading of the ammeter. Open the lower set and adjust the upper in the same way. Run the machine with both sets free, and the ammeter reading should fall within the limits above given.

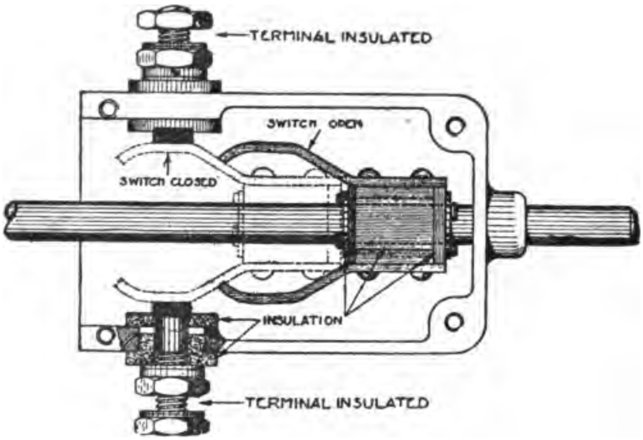
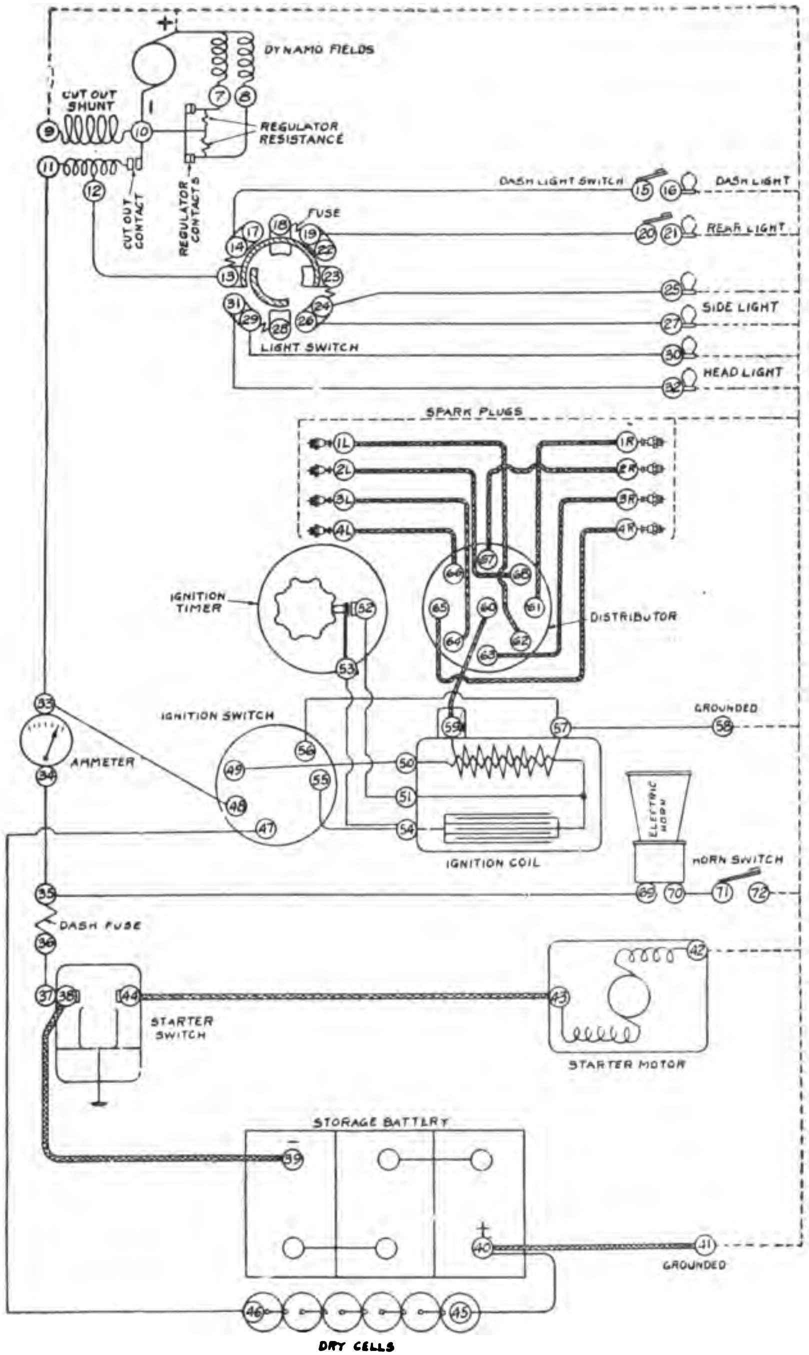


Fig. 283. Gray & Davis Starting Switch with Both Terminals Insulated

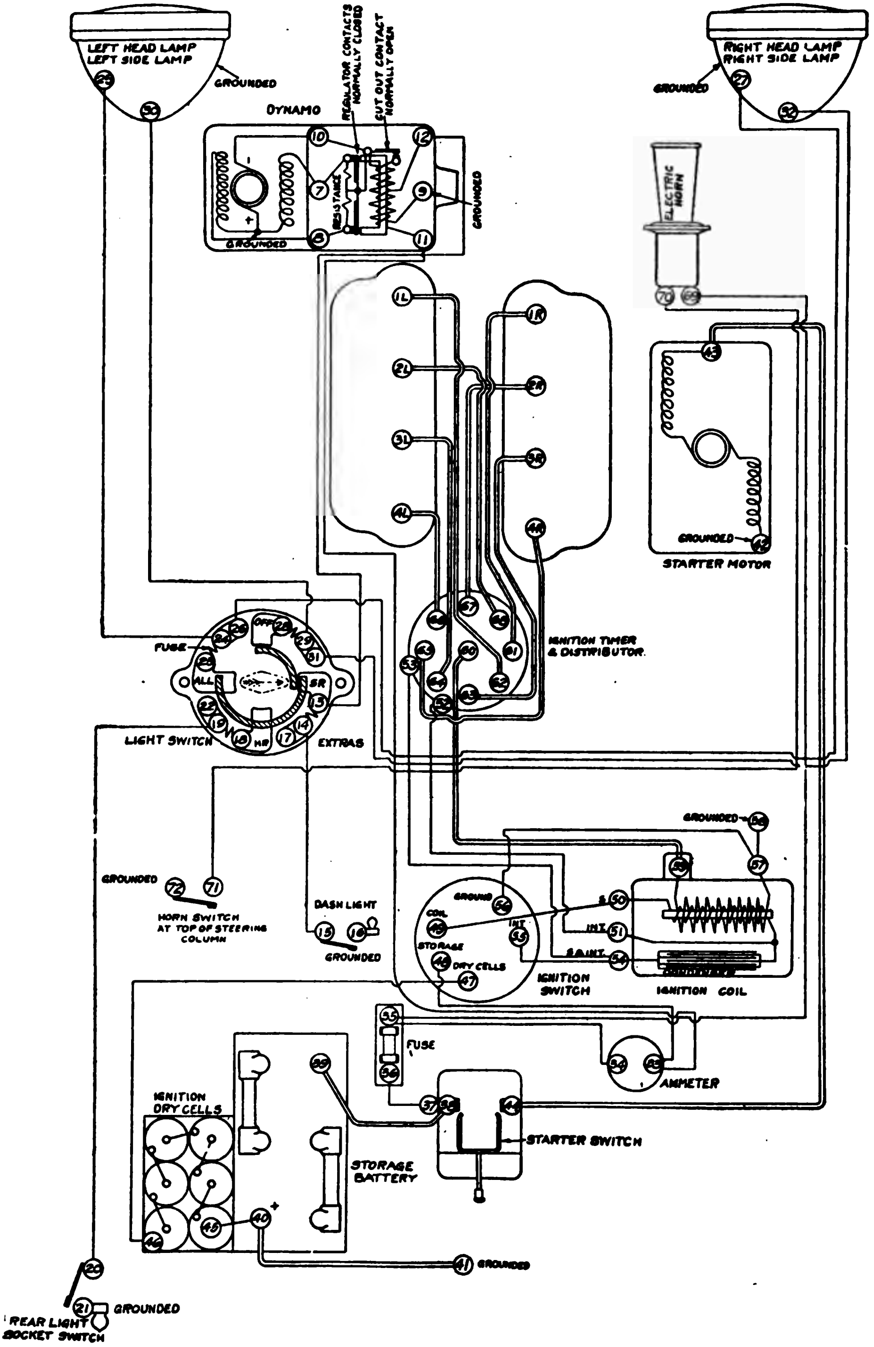
To Check Candle Power of Lamps. These instructions are given by the manufacturers in connection with a special bench testing set using three 15-c.p. lamps in multiple. Check the candle power of the lamps on the car to see that their total does not exceed 45 c.p., as 25-c.p. headlights are sometimes used. The employment of headlights of this high power should be discouraged by the garage man, as they needlessly increase the load on the battery and cause a blinding glare.

To Check for Closing Voltage. The points of the battery cut-out are designed to close at 6½ to 6 volts from the generator and are



Chassis Wiring Diagram for the Gray & Davis Starting and Lighting Installation on the Peerless, Model 56

Courtesy of Gray & Davis, Inc., Boston, Massachusetts

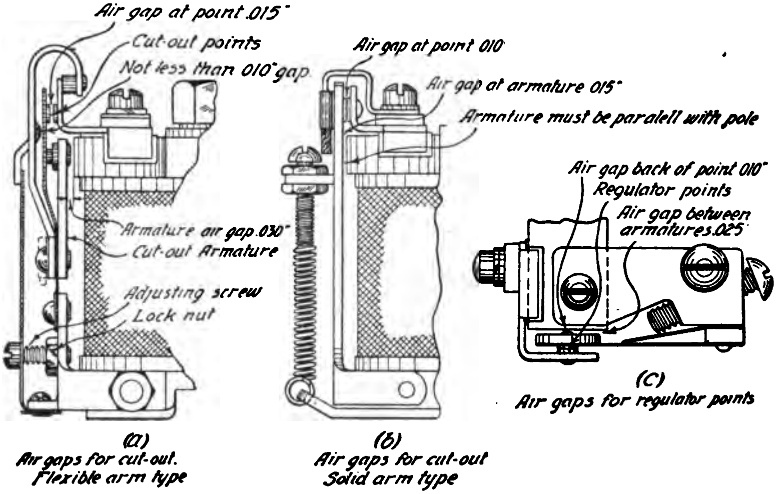


Electrical Diagram for Gray & Davis Starting and Lighting Installation on the Peerless, Model 56

Courtesy of Gray & Davis, Inc., Boston, Massachusetts

designed to open on a current of ½ to 2 amperes from the battery on discharge. Connect the low-reading voltmeter, scale 1 to 10 volts, across the generator brushes. Gradually speed up the generator and note the voltmeter reading to determine the voltage at which the points close. If not correct, adjust the cut-out spring to bring the closing voltage within the above limits.

To Check the Cutting-Out Point. Connect ammeter in battery and cut-out circuit, using low-reading shunt, 1 to 3 amperes. Have the machine running at a speed at which points are closed, and gradually slow down, observing the ammeter reading when the points open. If not within the limits given, adjust the cut-out spring to bring them within these limits by tightening or loosening the spring tension and repeating the test. Should this not be possible, inspect the points to see if they are clean and true, and, if in good condition, check the distances of the various air gaps between the points and between the armature and the pole piece, or stop, as shown in Fig. 284.



(a) Air gaps for cut-out. Flexible arm type

(b) Air gaps for cut-out Solid arm type

(c) Air gaps for regulator points

Fig. 284. Diagram Showing Air Gaps between Parts of Gray & Davis Apparatus

Wiring Diagrams. The single-wire system is standard, but in some cases the motor is grounded and in others the switch. Among others, the Gray & Davis system with grounded motor is installed on the Peerless, Chandler, Stearns, and Winton; with grounded switch, it is installed on the Chalmers, Paige, and Maxwell. It is

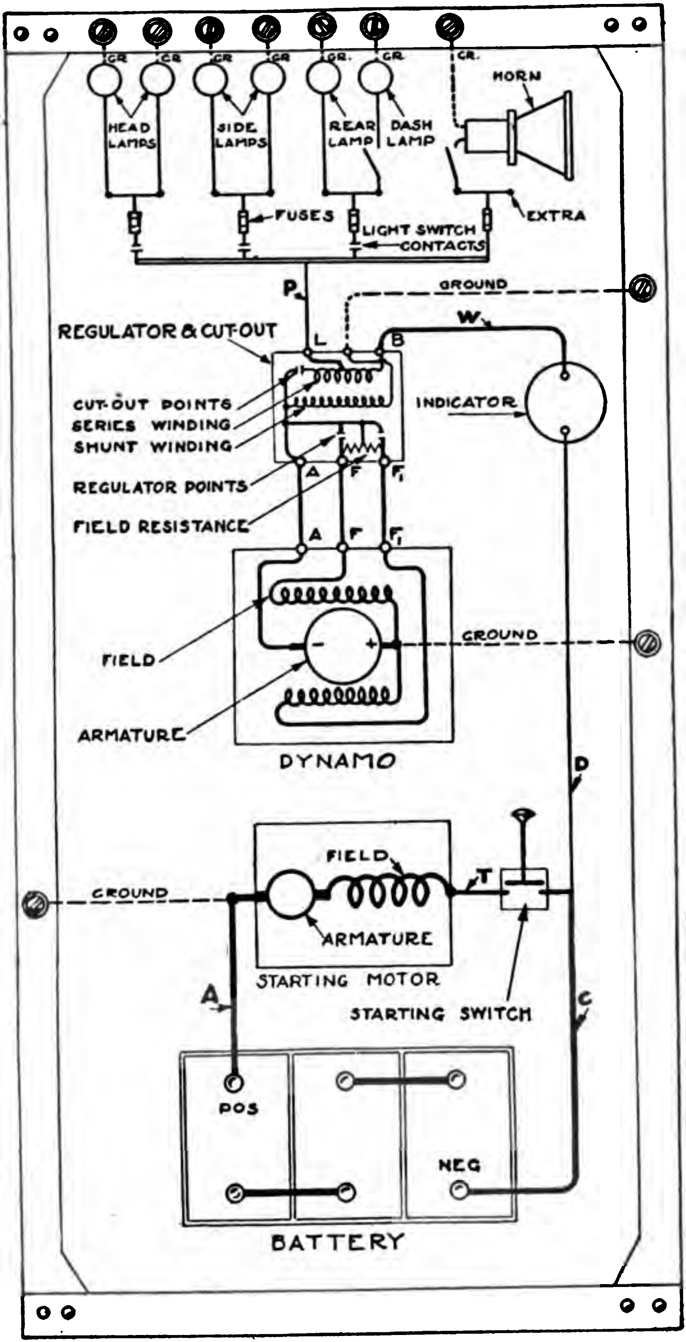


Fig. 285 Wiring Diagram for Gray & Davis Single-Wire System with Grounded Motor

naturally impossible to give complete lists of installations in any case, so that only one or two representative makes are mentioned to enable certain systems to be identified in the garage when desired.

Grounded-Motor Arrangement. Fig. 285 shows the Gray & Davis wiring diagram with grounded motor. Cable *A* from the battery positive terminal connects to the grounded terminal of the starting motor. Cable *T* connects an insulated terminal on the starting motor to one of the starting-switch terminals. Cable *C* from the starting switch terminal connects to the battery negative terminal, thus completing the circuit. On some makes of cars, cable *A* instead of connecting directly to the starting motor is connected to the frame of the car or *grounded.* The car frame carries the current to the grounded terminal of the starting motor. Wire *D* from the end of cable *C* at the starting switch connects to the lower terminal of the indicator (or ammeter). Wire *P* connects dynamo terminal *L* at the regulator to the lower terminal of block *B* at the lighting switch, Fig. 286 showing a rear view of the lighting switch. From the terminals at the fused side of *H* at the lighting switch, two wires connect to the right-hand and left-hand head lamps, while from the terminals at the fused side of *S* on the lighting switch corresponding wires connect to the two small lamps in the headlights. The tail lamp is connected from the fused side of *R* on the lighting switch and in some cases to the dash lamp, while the electric horn and ignition are

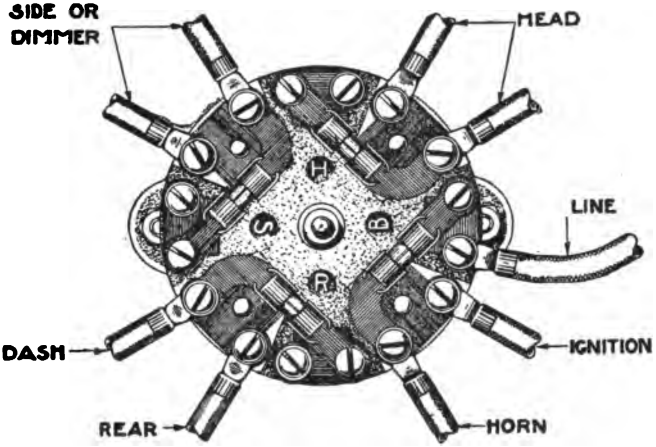


Fig. 286. Gray & Davis Lighting Switch, Rear View

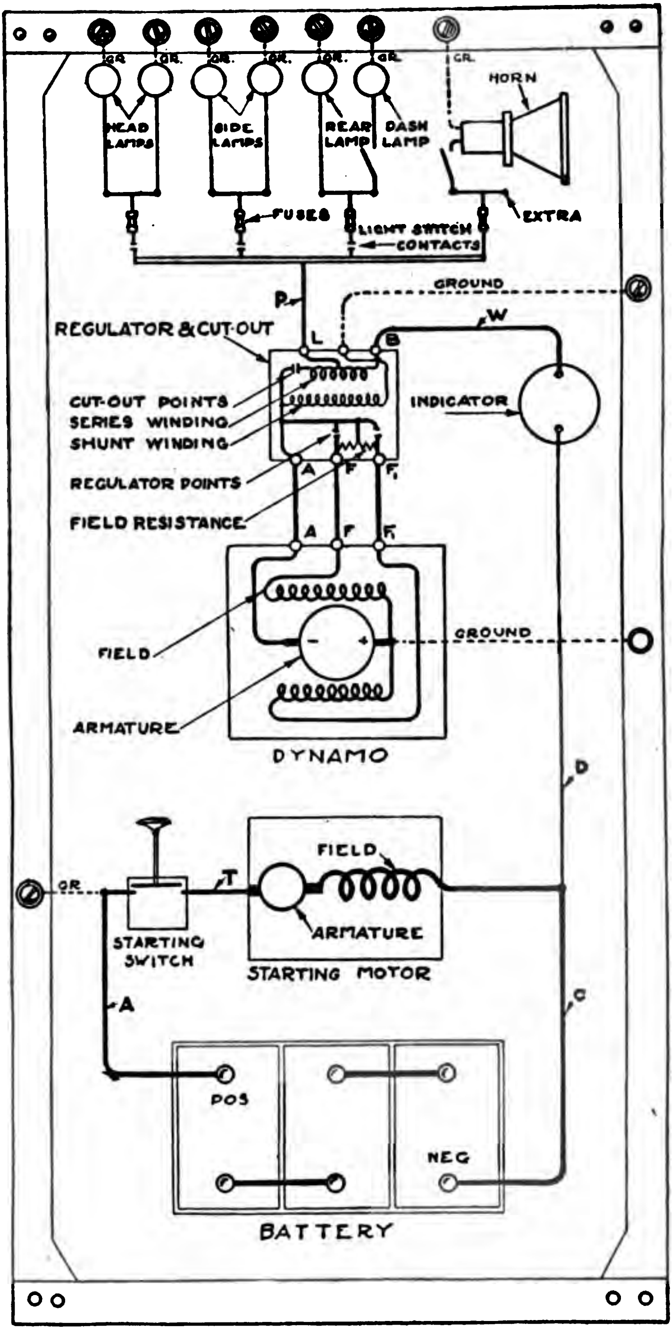


Fig. 287. Wiring Diagram for Gray & Davis Single-Wire System with Grounded Switch

connected to the fused side of *B*. The various ground connections are as follows: battery positive by cable *A* to frame at grounded terminal of starting motor; generator positive terminal to the frame of the dynamo itself; one side of all lamps to frame of car.

Grounded-Switch Arrangement. Fig. 287 is the Gray & Davis wiring diagram of the grounded-switch type. The only difference between this and the other diagram is that the ground connection is taken from the terminal of the cable *A* to the switch instead of from the motor.

Instructions. When the indicator does not indicate *charge* though the engine is speeded up, but indicates *discharge* with the engine stopped, the dynamo or the regulator may not be working properly. To verify this, turn on all the lights, run the engine at a speed equivalent to 10 miles per hour, disconnect the wire from terminal *B*, Fig. 285, at the regulator cut-out; if the lights fail, either the dynamo or the regulator is at fault. Reconnect the wire to terminal *B* and remove the side plate from the dynamo to examine the brushes. Slide the brushes in and out, and see that they slide freely in the brush holders and make good contact with the commutator and that the wires from the brush holders and the fields to the dynamo terminals are firmly connected. If the dynamo is belt-driven, the belt may not be tight enough to rotate the dynamo at sufficient speed to charge the battery. The commutator, if coated or dirty, may be cleaned while rotating by holding a cloth slightly moistened with oil against it.

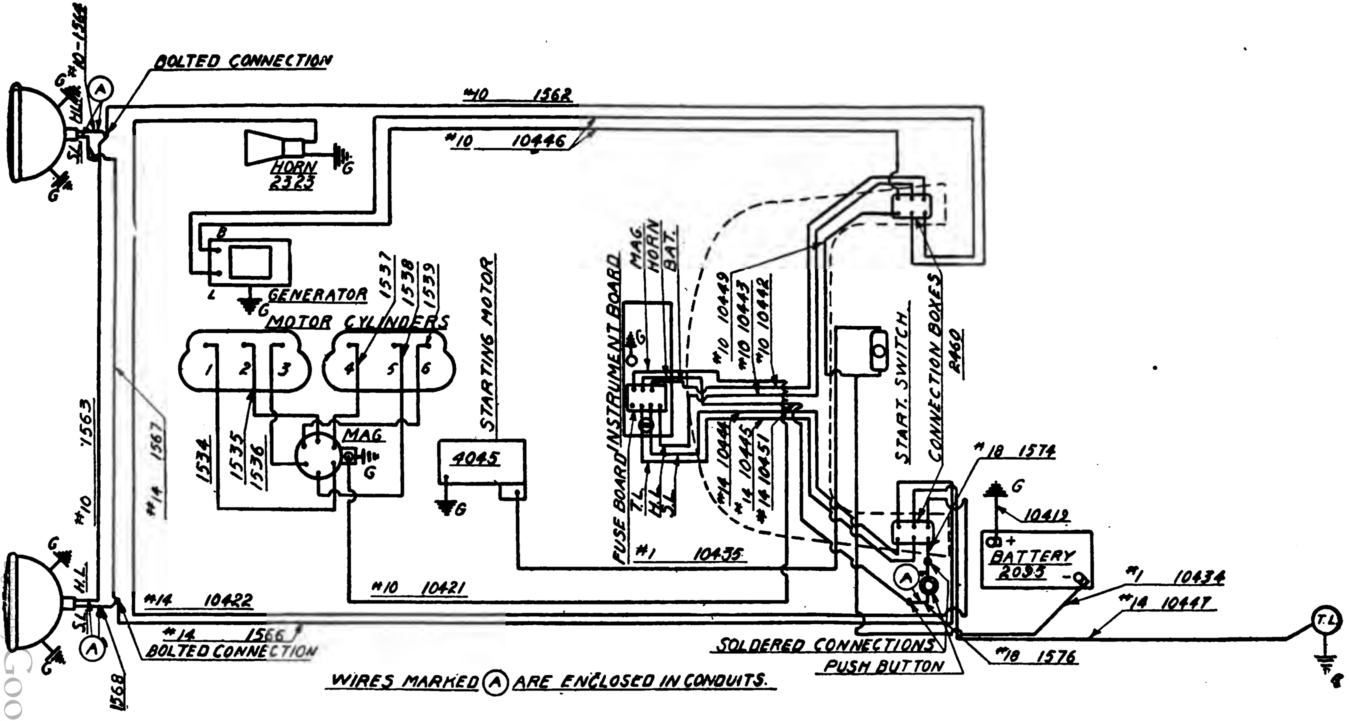
Should these tests fail to remedy trouble, connect a wire at the regulator cut-out from terminal *A* to terminal *B*. With lights off, speed the engine to the equivalent of 10 miles per hour. If the indicator then shows *charge*, the regulator cut-out is at fault. Note whether any connections on it are loose or broken from vibration. See that the contacts are clean and come together properly. Take a match stick or small piece of clean wood and press them together; if this remedies the trouble, the contact points are at fault. Clean them with a strip of fine emery cloth or with a very small fine flat file, not taking off any more than is necessary to clean and true up the points. In case this treatment does not put the cut-out in working condition again, the manufacturer's service department should be called on for assistance.

But if, under conditions just given, the indicator, or ammeter, shows neither *charge* nor *discharge,* the dynamo circuit is open. This may be from poor brush contact or from a loose or broken connection at some other point. If the indicator shows *discharge,* reduce the engine speed to the equivalent of 8 or 9 miles an hour; then while the engine is running, connect another wire from the dynamo terminals F and F_1 to terminal A. If the indicator then shows *charge,* the regulator is at fault, as this wire cuts the regulator out of the charging circuit. While making this test, care must be taken not to run the engine any faster than mentioned, as the dynamo is not protected by the regulator. If in this test, the indicator still shows *discharge,* it signifies that the dynamo field circuit is open or that the armature is short-circuited.

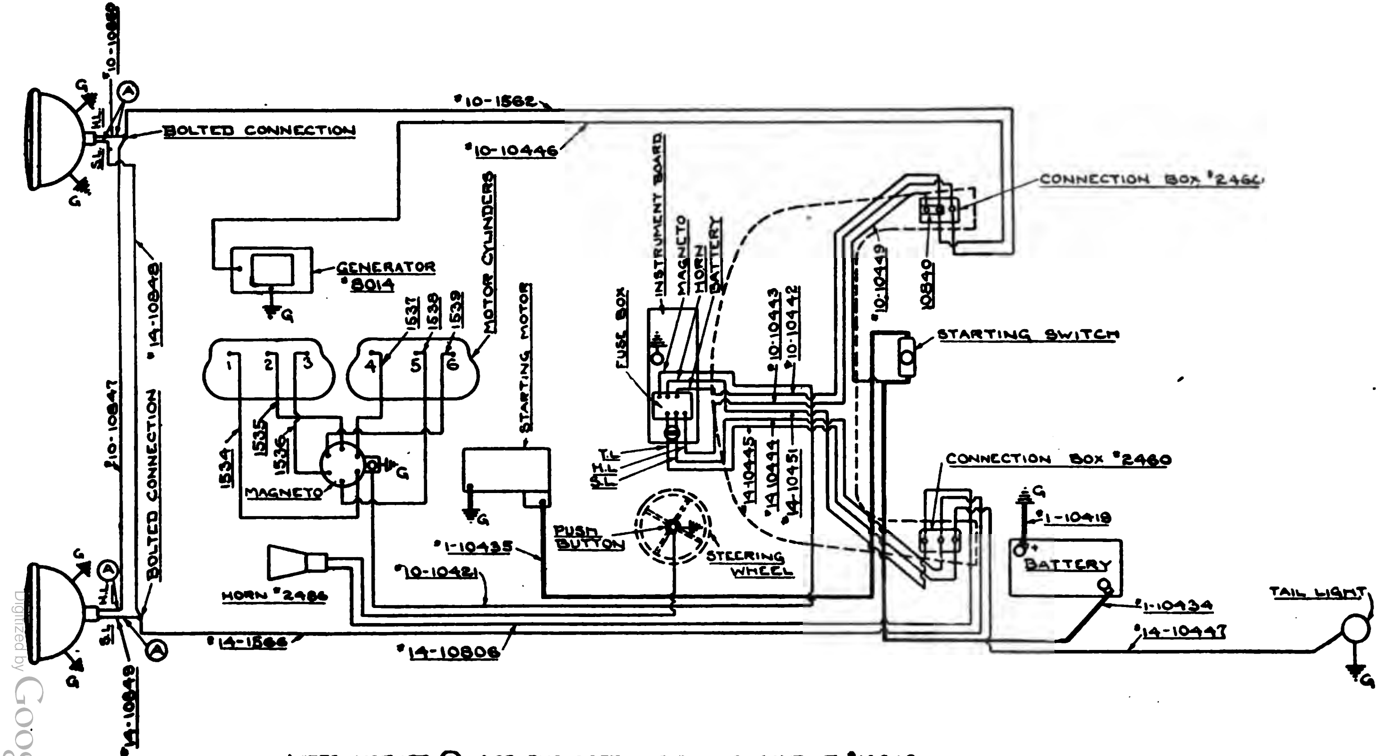
Loose Connections. If with the engine speeded up the indicator does not show *charge* and with the engine stopped and the lights turned on it does not indicate *discharge,* there is an open or loose connection in the battery circuit. See that all the wires are firmly connected and that the contact faces are clean. Or the indicator itself may be at fault. Verify this by disconnecting one wire from it and if it then returns to neutral, it indicates that some part of the wiring is grounded on the frame of the car and is causing a short-circuit which is discharging the battery. But if after disconnecting this wire the indicator shows *discharge,* it is at fault. See if the pointer is bent. This probably will be the case if it indicates *charge* with the engine stopped.

Short-Circuits. If the ammeter discharge reading is above normal, it may indicate that higher candle-power lamps have been substituted for the standard bulbs, or that some of the lamp wires are short-circuited. Intermittent jerking of the pointer from *charge* to *neutral* while the engine is being speeded up also indicates a short-circuit. Repeated blowing of fuses indicates short-circuited lamp wires or defective lamps. Trace the wires along their entire length and try new bulbs.

Starting-Motor Faults. If the motor does not rotate, the battery may be discharged. In case the engine has been overhauled just before, main bearings may have been put up so tight that the starting motor has not sufficient power to turn it over. The starting switch may not be making good contact, the motor brushes may not be



Gray & Davis Starting and Lighting Installation on the Chandler 1917 Light-Weight Six (Regular Series)
Courtesy of Gray & Davis, Inc., Boston, Massachusetts



WIRES MARKED Ⓐ ARE ENCLOSED IN FLEXIBLE CONDUIT *10846

Gray & Davis Starting and Lighting Installation on the Chandler 1917 Light-Weight Six (for Cars Numbered from 35001 to 60000)
Courtesy of Gray & Davis, Inc., Boston, Massachusetts

bearing properly on the commutator, or the battery terminals may not be tight. If the starting motor rotates but does not crank the engine, the over-running clutch may not be running properly or the engaging gears do not mesh. When the starting motor cranks the engine a few turns and stops, the battery is almost discharged. Unless the engine starts after the first few revolutions, do not continue to run the starting motor, as it will exhaust the battery very quickly. Look for causes of engine trouble—lack of gasoline, ignition circuit open, or the like.

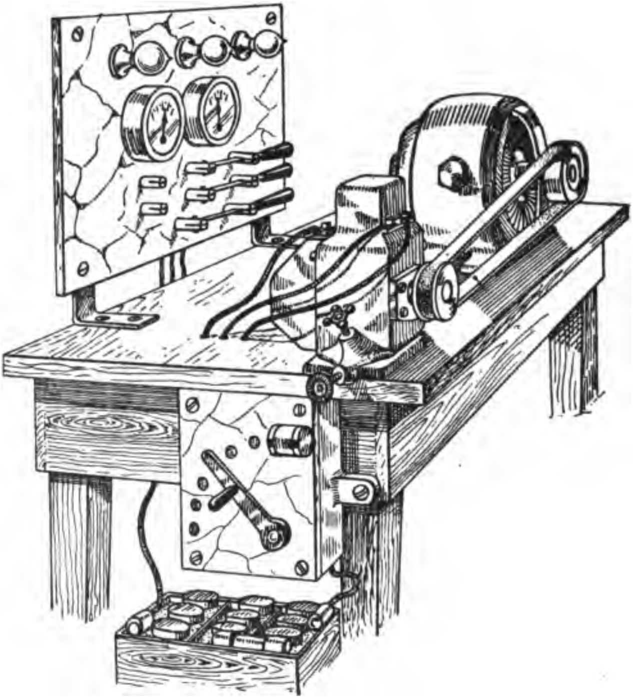


Fig. 288. Diagram of Layout for Testing Gray & Davis Generator
Courtesy of Gray & Davis, Boston, Massachusetts

Gray & Davis Service Tests. Garages caring for fifty or more cars find it profitable to install the equipment to carry out the necessary tests of electrical apparatus instead of referring every case that is beyond the ordinary requirements to the manufacturer or to one of its service stations. The makers recommend for testing generators and motors when removed from the car, the following apparatus:

(1) One ½-h.p. electric motor with variable speed rheostat (direct current) giving a speed range of 600 to 1800 r.p.m. This is where only one machine is to be tested at a time; for running several from a countershaft, a 1- to 2-h.p. motor is necessary. (2) Three motor pulleys, 2, 3, and 7½ inches in diameter, respectively, and three generator pulleys, 2¼, 3, and 5 inches in diameter. (3) Adjustable bases for holding generators. (These can be obtained from Gray & Davis.) (4) Portable voltmeter with a 15-volt scale. The instrument described for general testing will fill this requirement as well. (5) Ammeter with a charge and discharge reading to 25 amperes, i.e., 25—0—25. (6) One tachometer, or revolution counter. (7) Four Ediswan base sockets and three 15-c.p. 7-volt lamps. (8) One single-pole single-throw switch and two single-pole double-throw switches, all of 15-ampere capacity. (9) One 80-ampere-hour 6-volt storage battery. (10) Sufficient No. 10 flexible cable for making the necessary connections.

The above apparatus is more particularly for the generator tests. For making motor tests, the following are necessary:

(1) Ammeter reading to 400 amperes. (2) One spring scale reading to 20 pounds. (3) One single-pole single-throw switch of 200-ampere capacity. (4) Steel clamp and base for motor. (5) One 6-inch flanged iron pulley. (6) Sufficient No. 1 flexible cable for connections.

Generator Test Chart. In order to enable the tester to check the performance of the generator, the test chart, Table III, has been supplied. The method of mounting the ½-h.p. motor, switches, instruments, rheostat, and storage battery is shown in Fig. 288, while the wiring diagram showing the method of connecting up the various units is illustrated in Fig. 289. Referring to the test chart, Table III, column 1 gives the types of generators manufactured by Gray & Davis. To determine the type number, it is necessary to note only the first three numbers on the name plate. For instance, 2221541 indicates type 222, machine 1541. This applies to all machines of this make turned out since September, 1915.

Column 2 shows the amount of current required to run the generator as a motor, or to "motorize" it. To take this reading, the posts *AF* and *F-1* should be connected together with a copper wire and the wire from the battery connected to the post *A*. The ampere reading and the speed should be within 10 per cent of the figures given in column 2. If not, remove the regulator and repeat the test, column 3 showing the proper speed. If the armature is shorted it will take excessive current, the ammeter needle will fluctuate, and the speed will be below normal. If the current is excessive but steady and the speed is high, it will show a defect in the fields or the field connections, as indicated in succeeding paragraphs.

TABLE III

Test Chart for Gray & Davis Generators

Information for Service Stations

1	2	3	4	5	6	7	8	9	10
Type of Generator	Running Light as a Motor at 6 Volts		Low Speed Reading 10 Amp.	Amperes Charge to Battery with 7½ Amp. Lamp Load		Shunt Field Current at 6 Volts		Output of Dynamo with 7½ Amp. Load	
	Amp.	Speed (r.p.m.)		Max.	Min.	Max.	Min.	Max.	Min.
Chandler S	3	320	750	4.5	1	1.32	1.09	11	8.5
Paige S	3	320	750	6	1	1.32	1.09	12	8.5
Chalmers T	3	650	1300	4.5	1	1.30	1.04	11	8.5
Mets T	3	650	1300	4.5	1	1.30	1.04	11	8.5
M.G.9	10	700	8 Amp. 1575	4.5	1	1.20	.96	11	8.5
300	10	700	8 Amp. 1575	4.5	1	1.20	.96	11	8.5
301	10	700	8 Amp. 1575	4.5	1	1.20	.96	11	8.5
210	3	320	750	6	1	1.32	1.09	12	8.5
211	3	650	1300	4.5	1	1.30	1.04	11	8.5
212	3	650	1300	6	1	1.30	1.04	12	8.5
213	3	650	1300	6	1	1.30	1.04	12	8.5
214	3	650	1300	6	1	1.30	1.04	12	8.5
216	3	650	1300	6	1	1.30	1.04	12	8.5
217	3	650	1300	6	1	1.30	1.04	12	8.5
218	3	650	1300	6	1	1.30	1.04	12	8.5
219	3	650	1300	4.5	1	1.30	1.04	11	8.5
220	3	300	600	4.5	1	1.02	.77	11	8.5
222	3	335	700	4.5	1	1.02	.77	11	8.5
223	3	335	700	6	1	1.02	.77	12	8.5
224	3	300	600	6	1	1.02	.77	12	8.5
225	3	300	600	4.5	1	1.02	.77	11	8.5
226	3	335	700	4.5	1	1.02	.77	11	8.5
227	3	650	1300	6	1	1.30	1.04	12	8.5
228	3	650	1300	4.5	1	1.30	1.04	11	8.5
229	3	335	700	4.5	1	1.02	.77	11	8.5
230	3	335	700	6	1	1.02	.77	12	8.5
231	3	335	700	6	1	1.02	.77	12	8.5
232	3	300	600	6	1	1.02	.77	12	8.5
233	3	335	700	4.5	1	1.02	.77	11	8.5
234	3	650	1300	4.5	1	1.30	1.04	11	8.5
235	3	150	1300	4.5	1	1.30	1.04	11	8.5
236	3	300	600	6	1	1.02	.77	11	8.5
237	3	320	750	4.5	1	1.32	1.09	12	8.5
238	3	650	1300	4.5	1	2.60	2.08	11	8.5
239	3	650	1300	4.5	1	2.60	2.08	11	8.5
240	3	335	700	4.5	1	2.04	1.54	11	8.5
241	3	335	700	4.5	1	2.04	1.54	11	8.5
242	3	335	700	4.5	1	2.04	1.54	11	8.5
243	3	335	700	4.5	1	1.02	.77	11	8.5
244	3	335	700	4.5	1	2.04	1.54	11	8.5
245	3	300	600	4.5	1	2.04	1.54	11	8.5
246	3	335	700	6	1	2.04	1.54	12	8.5
247	3	300	600	6	1	2.04	1.54	12	8.5
248	3	300	600	4.5	1	2.04	1.54	11	8.5
249	3	335	700	4.5	1	2.04	1.54	11	8.5
250	3	335	700	4.5	1	2.30	2.04	11	8.5
251	3	335	700	4.5	1	2.30	2.04	11	8.5
252	3	335	700	4.5	1	2.30	2.04	11	8.5
253	3	300	600	4.5	1	2.30	2.04	11	8.5
254	3	335	700	6	1	2.30	2.04	12	8.5
255	3	300	600	6	1	2.30	2.04	12	8.5
256	3	300	600	4.5	1	2.30	2.04	11	8.5
257	3	335	700	4.5	1	2.30	2.04	11	8.5
258	3	335	700	4.5	1	2.30	2.04	11	8.5
259	3	300	600	6	1	2.30	2.04	12	8.5
260	3	335	700	4.5	1	1.02	.77	11	8.5
261	3	300	600	6	1	2.30	2.04	12	8.5
262	3	300	600	6	1	2.30	2.04	12	8.5

Column 4 affords a check on other defects in the machine. To take this reading, connect posts *A F* and *F-1* together in order to give full field current, place machine on test bench, and run with belt. Speed the machine up until the ammeter indicates 10 amperes with the three 15-c.p. lamps in circuit and the battery testing 1.250 or over with the hydrometer. Take a reading of the speed. This should not be higher than that given in column 4. A higher reading will indicate defective fields, a high-resistance armature, pole pieces loose in frame, slight short-circuit in armature, defective brush or brush contact at commutator, or dirty commutator.

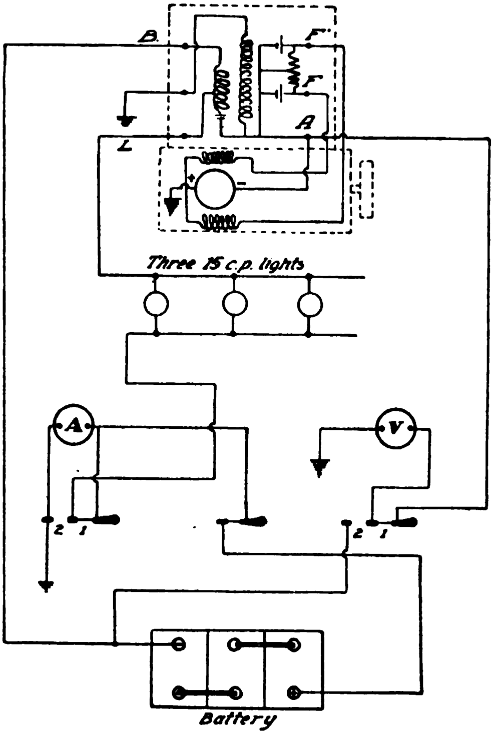


Fig. 289. Wiring Diagram for Gray & Davis Dynamo and Regulator

The purpose of columns 5 and 6 is to check the action of the regulator. To take this reading, turn on the three 15-c.p. lamps, giving a load of 7½ amperes, and observe the amount of current passing into the battery with the ammeter switch in position *2*. The reading should be within the limits shown in columns 5 and 6.

Columns 7 and 8 show the current taken by the field coils. Connect one side of the battery to the frame of the generator and the other side through the ammeter to terminal *F*. The reading should not be greater than column 7 or less than column 8. Repeat the test at terminal *F-1*. A high reading will show a short-circuit, and a low reading will show a poor connection or a high resistance in the field. No reading at all will indicate an open circuit in the field.

TABLE IV

Test Chart for Gray & Davis Starting Motor

1	2	3	4	5	6	7	8	9
TYPE OF MOTOR	RUNNING FREE READING				MINIMUM BRUSH PRESSURE (lb.)	GEAR REDUCTION IN GEAR HOUSING	1¼ LB. TORQUE READING AT 5¾ VOLTS	
	Max. Amp.	Speed 3 Volts	Speed 5.5 Volts	Speed 6 Volts			Amperes	Speed (r.p.m.)
100	35	3500	6600	7000	3½	None	137	2400
101	35	3500	6600	7000	3½	49–14	137	2400
102	35	3500	6600	7000	3½	47–16	137	2400
103	35	3500	6600	7000	3½	50–13	137	2400
104	35	3500	6600	7000	3½	50–13	137	2400
105	35	3500	6600	7000	3½	84–12	137	2400
106	35	3500	6600	7000	3½	51–12	137	2400
107	35	3500	6600	7000	3½	51–12	137	2400
108	35	3500	6600	7000	3½	50–13	137	2400
109	35	3500	6600	7000	3½	50–13	137	2400
110	35	1900	3800	4100	3½	51–24	98	1980
113	35	3500	6600	7000	3½	50–13	137	2400
115	35	3500	6600	7000	3½	50–13	137	2400
116	35	3500	6600	7000	3½	51–12	137	2400
117	35	3500	6600	7000	3½	51–12	137	2400
118	35	3500	6600	7000	3½	50–13	137	2400
119	35	2200	4500	5000	2¼	None	100	1660
120	35	2200	4500	5000	2¼	Direct	100	1660
121	35	2200	4500	5000	2¼	Direct	100	1660
122	35	1900	3800	4100	3½	Direct	98	1980
123	35	3500	6600	7000	3½	49–14	137	2400
124	35	3500	6600	7000	3½	51–12	137	2400
125	35	3500	6600	7000	3½	50–13	137	2400
126	35	2200	4500	5000	2¼	Direct	100	1660
127	35	2200	4500	5000	2¼	Direct	100	1660
128	35	3500	6600	7000	3½	51–12	137	2400
129	35	2200	4500	5000	2¼	54–12	100	1660
130	35	2200	4500	5000	2¼	Direct	100	1660
131	35	2200	4500	5000	2¼	Direct	100	1660
132	35	2200	4500	5000	2¼	Direct	100	1660
133	35	3500	6600	7000	3½	50–13	137	2400
134	35	3500	6600	7000	3½	50–13	137	2400
135	35	3500	6600	7000	3½	49–14	137	2400
136	35	3500	6600	7000	3½	49–14	137	2400
137	35	3500	6600	7000	3½	50–13	137	2400
138	35	2230	4500	5000	2¼	Direct	100	1660
139	35	2230	4500	5000	2¼	Direct	100	1660
140	35	2230	4500	5000	2¼	Direct	100	1660
141	35	1900	3800	4100	3½	Direct	98	1980
142	35	1900	3800	4100	3½	51–24	98	1980

Columns 9 and 10 show the current output for which the generator is set at the factory. To test this, place the ammeter switch in position *1* and with the three 15-c.p. lamps turned on speed the machine above 1750 r.p.m. If the reading does not fall within the limits given, adjust the regulator in accordance with instructions given below.

Starting-Motor Test Chart. Table IV is provided for reference in cases where the motor trouble is of such a nature that it cannot be located except by a test, i.e., in the windings. Column 1 gives the types of starting motors, which may be identified in manner the same as the generators. The type number covers the motor and the speed reducer.

Column 2 shows the current required to run the motor free. The reading should not vary by more than 25 per cent from the figures given. A high reading will indicate tight bearings, short-circuited armature, or field.

Columns 3, 4, and 5 show the speed when running light with current at 3 volts, 5½ volts, and 6 volts. The test should be made with either two or three cells of the battery. A low-speed reading with normal current will indicate loose connections, poor brush contact, dirty commutator, or high resistance in armature. A high-speed reading will indicate a short-circuit in the field windings.

Column 6 gives the spring pressure on the brushes. Where the brushes show a tendency to spark, this brush pressure should be checked. This reading is taken with a small spring scale hooked on to the brush screw. Read the number of pounds required to just lift the brush from the commutator. The reading should not be less than the figures given in column 6. Column 7 gives the reduction between the starting-motor shaft and the countershaft which carries the sliding gear.

Columns 8 and 9 are readings showing whether or not the motor is capable of delivering its rated power on normal current consumption and at normal speed. The reading is taken by putting on the shaft a load requiring a turning power of 1½ pounds at a 1-foot radius. To take this reading the flanged pulley, spring scale, and a cord are employed in the manner shown in Fig. 290. The reading on the scale corresponding to 1½ foot-pounds will be 6 pounds. Thus: 1½ foot-pounds times 12 inches equals 18 inch-pounds, which divided by 3 inches (radius of pulley) gives 6 pounds (scale reading).

To take the reading, close the switch and put just enough tension on the cord *A* to make the scale read 6 pounds and, holding this steady, read volts, amperes, and speed. The speed given in column 9 is taken at 5¾ volts, which is what would be obtained with a battery showing 1,250 or over on the hydrometer test. A lower voltage will cause a lower speed reading. In the majority of cases, tests made with the motor running free will show any defects, but in case these tests do not reveal any trouble and the motor still fails to operate satisfactorily, the tests for which the proper figures are given in columns 8 and 9 should be carried out.

To Adjust Cut-Out. The contact points should close to permit the battery to charge at 6 to 6½ volts; they should open the circuit between the battery and the generator on a discharge of ½ to 2 amperes. To test the cut-out, connect the voltmeter across the generator brushes or have the voltmeter switch in position *1*, Fig. 289. Gradually speed up the generator and observe the voltmeter to determine the closing voltage. The closing voltage is the reading on the voltmeter at the instant that the cut-out points come together. Adjust the cut-out spring to bring the closing voltage within the limits given above. With the lamps turned off and the ammeter switch in position *1*, slow the machine down and observe the ammeter reading when the cut-out points open. Adjust the cut-out spring to make this reading fall within the above limits. In case a satisfactory result is

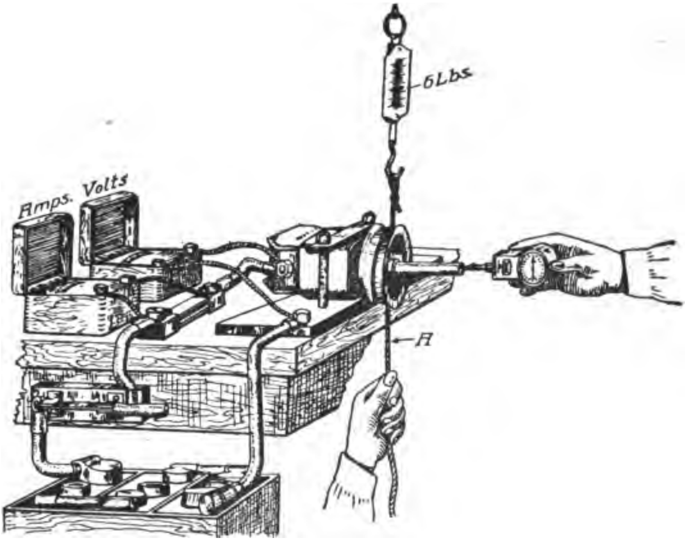


Fig. 290. Set-Up for Testing Power of Motor
Courtesy of Gray & Davis, Boston, Massachusetts

not obtainable after several attempts at adjusting the spring, check the air-gap distances, as given below. Correct these and test again.

To Adjust Regulator. With all connections made and the ammeter switch in position *1*, turn on the three 15-c.p. lamps and speed the machine up to above 1750 r.p.m. Open the upper set of points with the aid of a match or by using the finger. Adjust the lower set of points by the ammeter reading so as to bring it within the limits given in columns 9 and 10 of the generator test chart. Repeat the adjustment on the upper set, opening the lower set while the test is being made. Run the machine with both sets of points free and the reading should fall within the limits given in columns 9 and 10.

HEINZE-SPRINGFIELD SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. The generator is of the multipolar shunt-wound type (four poles) with brushes spaced 90 degrees apart, bringing both on the left side of the commutator to make them more accessible. The negative, or lower, brush of the generator, Fig. 291, is grounded to the brush holder, which, in turn, is grounded on the generator brush head. From the positive, or upper, brush a wire runs to the terminal GEN. BR.+ of the regulator and cut-out, Fig. 292. From this terminal, the charging circuit leads to the cut-out contacts and through the latter and the series winding to the terminal BAT+ of the regulator cut-out. As the negative brush of the generator is grounded, the negative terminal of the battery and one side of all the lights are grounded. One end of the generator shunt field is grounded inside to the generator frame. The other end comes out through the hole provided for it in the brush head, runs to the terminal FLD of the regulator cut-out, and thence to the contacts of the current regulator if they are closed, or through a resistance if they are open.

Starting Motor. The starting motor is of the four-pole series-wound type with the brushes at 90 degrees apart, as on the generator. The positive brush is on top of the commutator and carries a terminal to which is connected the starting cable. The lead from the negative brush divides, part of the current passing around two of the four poles to the ground, while the other part passes through the other two poles to the ground connection. On starting motors bearing serial numbers

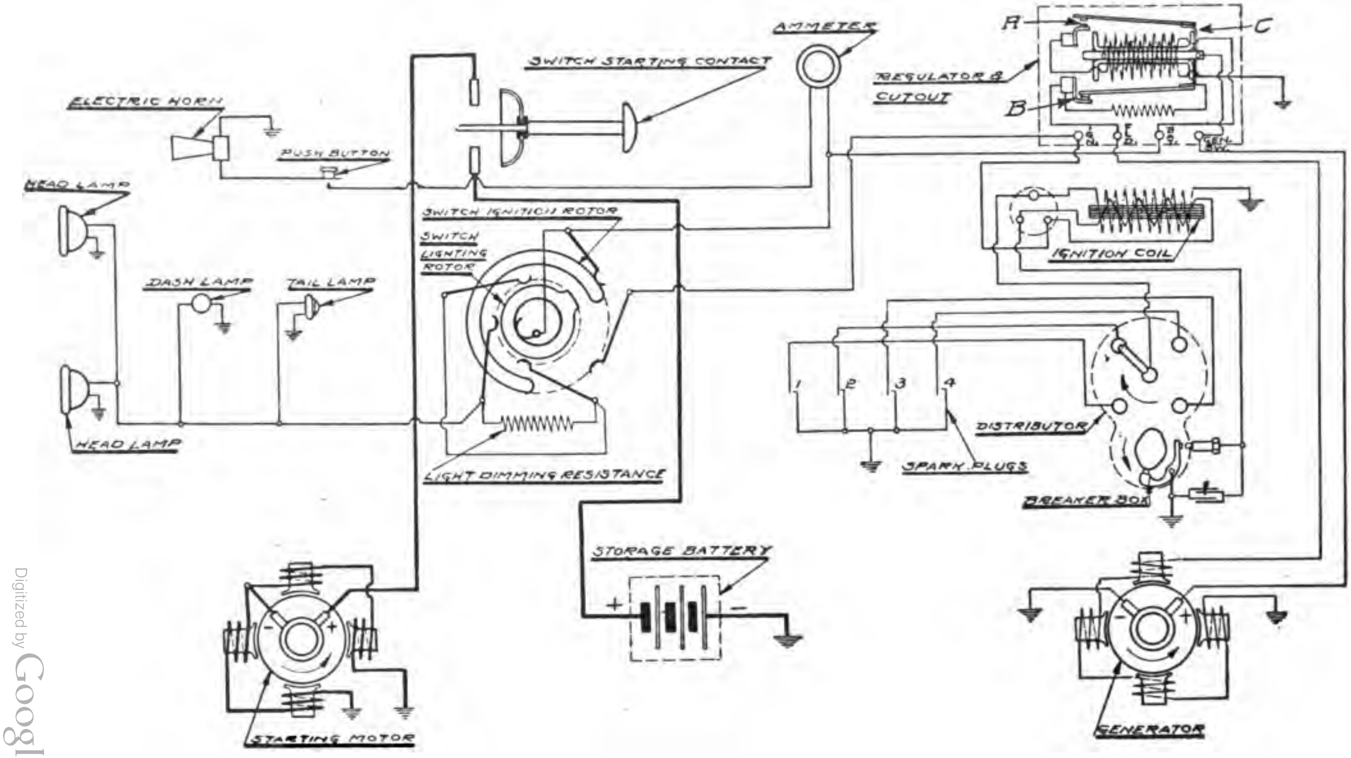


Fig. 291. Internal and External Wiring Diagram for Heinse-Springfield System on Regal Car

below 5471, the grounded ends of the series fields were soldered to the pole pieces, but this has since been altered by securing the two ends of the series field to a ground lead, which, in turn, is secured to the bottom of the motor brush head by means of a hexagonal nut and lock washer.

While the system is of the two-unit type and the units are independent of each other electrically, they are combined mechanically by making the rear heads of both in one casting. The starting motor is the upper of the two units, the lighting generator being placed directly beneath it. This refers to the set supplied for installation on the Ford.

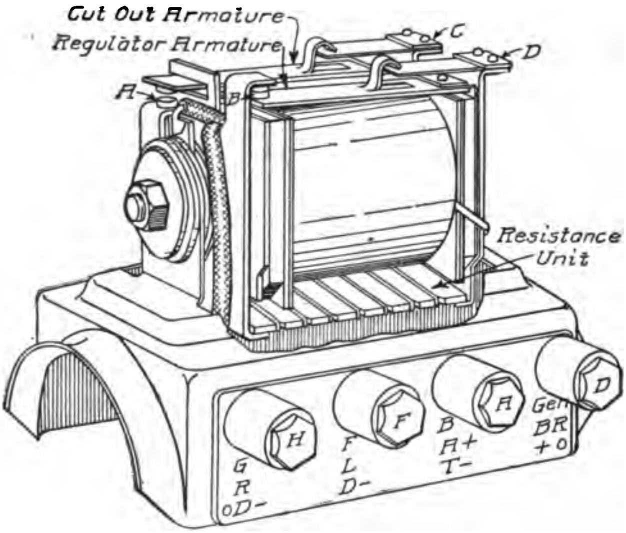


Fig. 292. Heinze-Springfield Current Regulator and Battery Cut-Out

Method of Operation. Drive is by means of a silent chain directly to the sprocket on the generator shaft. In addition to the sprocket in question, the generator shaft carries also a large gear adapted to mesh with the small pinion on the shaft of the Bendix drive mounted on the shaft of the starting motor. When the starting motor rotates, the Bendix pinion automatically engages the gear on the generator shaft and drives to the engine through the silent chain, the engagement being broken as soon as the engine turns over under its own power.

Regulation. *Voltage Regulator and Resistance.* The current regulator is combined with the battery cut-out and the combined unit is mounted directly on the starting motor, Fig. 292. The regulator side of the relay consists of two contacts *B*, which are normally held together by spring tension so that the charging current does not exceed 10 to 12 amperes. When the voltage rises above a certain value owing to the increased speed of the engine, the regulator armature is drawn down, separating the contacts, and the current must then pass through the resistance unit shown beneath the coil. This keeps the charging current down to the value mentioned.

On the battery cut-out side, the relay consists of two contacts *A*, which are normally held apart by spring tension when the engine is not running or is running too slowly to charge the battery. As soon as it is running fast enough to generate sufficient voltage to overcome that of the storage battery, the regulator armature is drawn down, closing the contacts. This occurs at an engine speed equivalent to about 6 miles per hour, at or above which the battery is always charging. When the speed decreases to below this point, the pull on the armature is not sufficient to hold it down, and the contacts are separated by the spring *C*.

Starting Switch. The starting switch is a combination dash switch designed to control the starting, lighting, and ignition. In the Ford set, the current for starting and lighting is furnished by the battery, while the current for ignition comes from the Ford magneto. Starting is accomplished by depressing the button in the center of the switch, while the lights are controlled by rotating the switch lever. By rotating the switch lever, the ignition rotor connects the contacts *M* and *C*, Fig. 399, in the IGN. ON position and allows current to flow from the magneto through the switch, coil, and plug connections. The lighting rotor of the switch is always supplied with current from the battery through a sliding contact of the wiping type. When at the "Lights Dim" position, the current passes through the dimming resistance, the ignition remaining undisturbed by this change. The switch is designed to lock both the starting contact and the lighting and ignition lever in the IGN. OFF "Lights Dim" position for parking at night, and in the OFF position for the daytime.

Instruments and Protective Devices. Unless specially ordered, an ammeter is not provided with the system designed for the Ford but may be had at an extra cost in the form of a combination panel carrying the switch, the ammeter, and a dash light. The regulator and the cut-out serve to protect the generator and the battery, respectively.

Wiring Diagram. As installed on the Ford, including an ammeter and dash lamp as just mentioned, the details of the wiring are shown in Fig. 401. The negative side of both the generator and the starting motor are grounded, the connection being split in the latter case and two grounds made. The negative side of the battery and one side of all the lamps and the horn as well are accordingly grounded. As ignition current is supplied by the magneto, the only connection of the ignition system with the lighting and starting system is at the combination switch. The charging current from the generator passes through the regulator (lower set of contacts) and when the engine is running at a speed equivalent to 6 miles an hour or more, the armature of the cut-out is pulled down and the upper set of contacts closes. This sends the charging current through the battery. Should the car be driven at a speed which causes the output of the generator to exceed 10 to 12 amperes, the regulator armature is attracted and the regulator contacts separate, thus shunting the current through a resistance which immediately serves to decrease the excitation of the generator fields and correspondingly reduces the current output of the latter. When the speed of the engine drops below a point where the voltage generated is insufficient to charge the battery, the cut-out contacts are separated by the spring, as the pull of the magnet is then not strong enough to hold it down. The lights are supplied directly from the battery, as will be noted, the diagram making clear the various positions of the rotating switch to give the different combinations available. The various connections and their significance will be clear upon comparing this with other and similar wiring diagrams.

Instructions. Failure of the starting motor to operate is usually caused by lack of current in the storage battery, although this fault may be due to several causes, acting either separately or together. Lack of charge in the battery is usually caused by over-frequent use of the starting system with but little driving between, so that the generator is not given an opportunity to charge the battery. Other causes of failure are treated under Starting and Lighting Storage Batteries, in another section.

Starting Motor. The starting motor may not operate because of internal trouble. This may take the form of an open- or short-circuited armature or field, dirty commutator, insufficient tension on brushes, brushes not bearing on commutator, or grounded brush holders, armature, or field. Of these various causes of failure, the first is liable to be the most rare. For their correction see the various sections on testing for grounds and short-circuits with the aid of the ammeter also on care of commutator and brushes, given in connection with the description of other systems. The attention required is identical in practically every case and, where the brushes and the commutator are concerned, does not vary even in detail on the different systems.

Bendix Drive. Failure of the Bendix drive to operate properly may be due to lubricating the screw shaft, on which no oil or grease is necessary, since it will work better without it. Putting oil on this shaft makes impossible the "running start", which is the great advantage of the Bendix drive, i.e., the starting motor should almost instantly attain a high speed the moment the current is turned on, but the Bendix pinion will not move for a perceptible interval. When the Bendix pinion does move, the starting motor is running so fast that, at the moment the pinion engages suddenly, owing to the action of the spring, the engine is turned over the first compression very much easier than if the motor had to start nuder load.

Generator. Trouble in the generator will usually be manifested by the failure of the machine to generate a terminal voltage. The first warning would be the absence of any reading at the ammeter when the generator should be charging, the engine then running at a speed equivalent to 6 miles an hour, or over. If no ammeter is employed, the discharged condition of the battery may be traced either to the generator or to failure to drive the car sufficiently during the daytime and between starts to keep the battery charged. If, upon test with the hydrometer, the battery indicates rapid recuperation after the engine has been running for 15 to 30 minutes, the generator is not at fault. Should the battery specific-gravity test not show any improvement after running 30 minutes, the fault may be either in the generator or in the regulator cut-out. As is the case with the starting motor, defects in the generator may take the form of a dirty commutator, badly worn brushes, insufficient tension of brush springs to keep the brushes bearing on the commutator; the positive brush may be grounded; or there may be open-circuits or grounds, or short-circuits or grounds in the field or armature. In any case, the attention necessary will be the same as that already outlined for similar faults on other systems.

Regulator and Cut-Out. The regulator and cut-out consist of a single electromagnet with a split core on which there are two windings. The primary is in series with main charging circuit and the secondary is shunted across the motor brushes. If the generator is at fault, the battery cut-out naturally will not work, as there will be no voltage to operate it; but there will be times when the generator is working all right and the regulator is at fault, although it may be difficult at first sight to make sure which is the cause of the trouble. To determine this, with the engine running at a speed equivalent to 6 miles an hour or more, press the battery cut-out contacts together with the fingers. If the ammeter then shows a charge reading, and there is no dash ammeter, a weight may be placed on the cut-out armature to keep the contacts together for 30 minutes or so, and if the battery then shows that it is charging, the cut-out and not the generator is at fault. If, with the cut-out contacts thus held together, there is no sign of charging the battery, the generator is the cause of the trouble.

To adjust the regulator and cut-out, first adjust the regulator side, as the cut-out is dependent upon the regulator adjustment. Before starting the engine, remove the regulator and the cut-out cover, then remove the wire to the terminal "BAT+" and insert an ammeter in the charging circuit at this point, though if there be an ammeter on the dash, it may be used. Start the engine and run it very slowly. See that the regulator contacts are together, Fig. 292. At a speed equivalent to 6 miles an hour or over, the cut-out contacts *A* should close, and with the contacts at *B* closed, the ammeter should show a reading of 4 amperes. If contacts *A* do not close at this point, there may be too much tension on the spring, which may be remedied by bending the spring-holding support upward at *C*. Should the ammeter reading go above 10 to 12 amperes as the speed increases, this is due to the contacts *B* of the regulator not opening as they should. The tension of the armature spring of the regulator should then be lessened by bending the spring-holding support slightly upward at *D*. Note very carefully as the engine speed is decreased that there is enough spring tension on the cut-out armature to open the contacts *A* when the relay is demagnetized, due to the voltage of the battery exceeding that of the generator.

Trouble in the regulator and cut-out will manifest itself in two ways—insufficient charging current or no charging current reaching the battery and too much current at the higher car speeds. It may be due to several causes, acting either separately or collectively—the armatures springs may be out of adjustment; the current or voltage windings may be short-circuited, open, or grounded; the two sets of contacts may be dirty; or the resistance unit may be open. If the ammeter reading fluctuates though the engine speed remains constant, it is an indication of dirty contacts. They should be trued up with a file. If the regulator has failed, the current may have attained a value of 30 to 40 amperes and caused the contacts to fuse together. Separate and file clean.

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART II

1. What is meant by "polarization" in batteries?

2. (a) Explain how soot forms on the spark plug. (b) Give its effect on ignition. (c) Tell how this trouble is overcome in the design of the spark plug.

3. What is the characteristic of the Duplex ignition system?

4. Sketch the Dixie magneto.

5. Describe and illustrate a single-cylinder high-tension ignition system.

6. Give the possible firing orders in a 6-cylinder motor.

7. Give a complete discussion of ignition setting as used on the Hudson.

8. Give two reasons why the coil and vibrator are unsatisfactory for ignition work.

9. (a) Why should an engine never be driven at normal speed with the spark retarded? (b) When is retardation necessary; why?

10. Give diagram of a single-cylinder low-tension ignition system. Why is it not used for automobile engines?

11. What size cable must be used where the maximum current at starting is 250 amperes and the distance between the battery and the starting motor is 5 feet?

12. When a Dyneto system is installed, what is the maximum allowable voltage between the motor and the storage battery and what is the allowable loss in the cable?

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART III

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1. What type of contact-breaker is used on the Westinghouse and Remy generators?

2. How is excessive manipulation of the spark-advance lever overcome in the Westinghouse system?

3. Describe the operation of an Atwater Kent unisparker.

4. Show by sketch the proper connections for the Connecticut ignition system.

5. Describe the operation of the ignition relay formerly used in the Delco system.

6. What is meant by "crowning" a spring?

7. Give the three general causes for failure of ignition circuits.

8. Describe briefly and give diagram of a magnet recharger.

9. Give a list of possible causes for trouble in a contact-breaker

10. What type of interrupter should be used for high-speed engines?

11. What type of interrupter is used in the Connecticut battery system?

12. Give a short discussion of methods which should be used in detecting grounds in an electrical system.

13. What method was used to connect the ignition relay on the Delco Junior system for 1914?

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